THE PHILIPPINE JOURNAL OF SCIENCE

January–March 1992 ISSN 0031-7683 VOLUME 121 NO.1

CONTENTS

CHEONG,RONALD M.T .,GALLARDO ,W.G. and TOLEDO, J. D.
A Market Survey of Snappers (Genus Lutjanus) from Panay and Palawan Waters 1

MANALO, JOSEFINA B. , HOON HAN, B., PARK ,M.H. and SANTOS, R.B.
Purification and Characterization of Hypaphorine from the Seeds of Erythrina Variegata L. Var. Philippinensis (Linn.) Merr. Fam. Leguminosae 17

LIM-SYLIANCO,CLARA Y. , SYLIANCO-WU, L. and BOTUYAN,M.V.
Inhibitory Effects of Free Glutamate, Guanosine Monophosphate, Inosine Monophosphate and a Flavour Enhancer on Bone Marrow Genotoxicity of Dimethylnitrosamine 25

ARIDA,VIOLETA P., ATIENZA,O.G., QUILAO, T.A., CABALLERO, A.R., LAXAMANA, J.S. , PUGAL,D.L. and GUCE,C.P.
Production of High Quality Adsorbent Charcoal from Phil. Woods II. Granulated Activated Carbon 31

BEGUM ,FARIDA and NAZNEEN,SAIYIDA
Systematic Study of Molluscan Fauna of Layari River, Part 7: Bivalves (Palaeoheterodonta) 53

PAL,U., NANDA, T. , PAL, S. and NANDA,D.K.
Morphometric Analysis and Surface Ultrastructure of Ecdysial Gland Corresponding to the Stages of Moulting and Metamorphosis of Periplaneta Americana 65

SAMONTE, HENRY P. , TOLOSA, R. L. , JARIEL, D.E. and AGLIBUT, T.E.
Fertility Status and Amelioration Requirement of Soils Affected by Mine Tailings 73

THE PHILIPPINE JOURNAL OF SCIENCE

JANUARY – MARCH 1992 ISSN 0031–7683 Vol. 121 No.1

A MARKET SURVEY OF SNAPPERS (GENUS LUTJANUS) FROM PANAY AND PALAWAN WATERS

RONALD M.T. CHEONG, WENRESTI G. GALLARDO
and JOEBERT D. TOLEDO
SEAFDEC[1], Iloilo City, Philippines

ABSTRACT

Thirteen species of snappers (genus Lutjanus) were identified and sourced for location of capture from surveys conducted at the Iloilo Fishing Port and Central Market. They were Lutjanus argentimaculatus, Lutjanus boutton, Lutjanus carponotatus, Lutjanus decussatus, Lutjannus fulviflamma, Lutjanus malabaricus, Lutjanus monostigma, Lutjanus quinquelineatus, Lutjanus rivulatus and Lutjanus vitta. Incidence of lutjanids was year round with a peak in May. Most abundant and commonly observed were Lutjanus vitta, Lutjanus gibbus and Lutjanus argentimaculatus.

INTRODUCTION

The family Lutjanidae is divided into four sub-families namely Lutjaninae, Paradicichthyinae, Etelinae and Apsilinae representing 103 species in 17 genera (Allen, 1985). The genus *Lutjanus* in the sub-family Lutjaninae possesses the greatest number of species with 65, of which 39 have been documented in the Indo-West Pacific. Herre (1953) described 32 species of *Lutjanus* in the Philippines. Snappers command a relatively high market price in the ASEAN region with strong demand both in the local and export markets (FAO, 1990). Presently, floating net cage culture of *Lutjanus johnii* and *Lutjanus argentimaculatus* is being practice in Singapore, Indonesia and the Philippines (Cheong, 1990; FAO, 1990). Culture of snappers has a high potential as it is still a developing industry.

This study investigated species and seasonality of lutjanids available in Panay as candidate species for culture.

---

1 Southeast Asian Fisheries Development Center (SEAFDEC)

2

MATERIALS AND METHODS

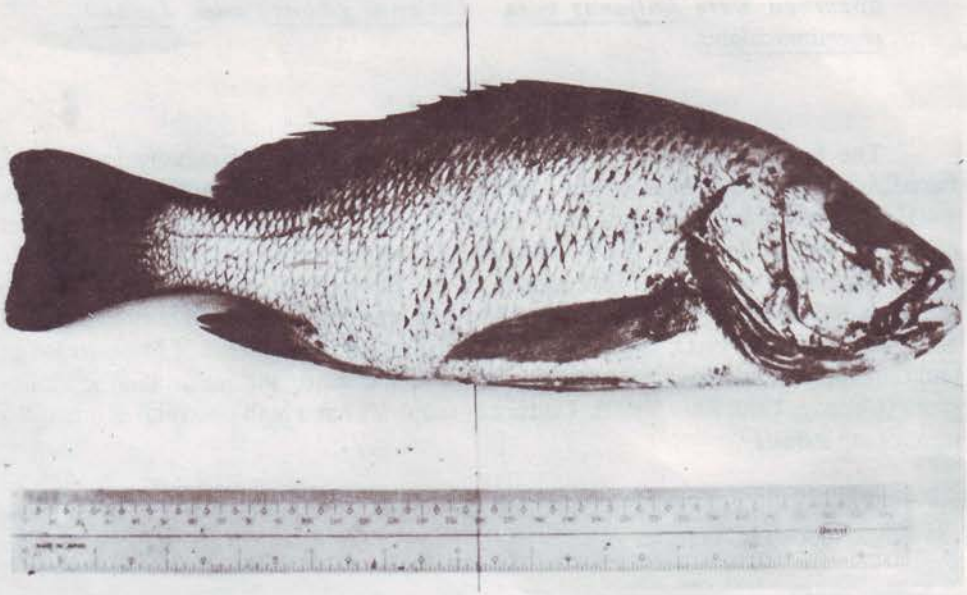
Bi-weekly sampling was conducted for one year at the Iloilo Fishing Port starting July 1990. The fishing port was visited between 12.45 AM-3 AM when the majority of fish were landed. Fish were sourced for location of capture through interviews. Specimens were identified, photo documented while fresh, and preserved in the 10% formalin for future reference. From October 1990, the Iloilo Central Market was included in the sampling schedule, and thereafter the fishing port and the market were each sampled once a month.

RESULTS AND DISCUSSION

It was assumed that Iloilo Fishing Port would provide a representative sample of lutjanids since the majority of fish that are landed there come from around Panay. The Central Market was later included to complement fish caught in Iloilo and the adjacent island of Guimaras.

Thirteen species of lutjanids were identified from color patterns, and verified according to Masuda et. al. (1984); Allen (1985); and Lee (1987).

1. *Lutjanus argentimaculatus* (Forsskal, 1775)
Specimen: 310 mm SL; Central Market, January 1991

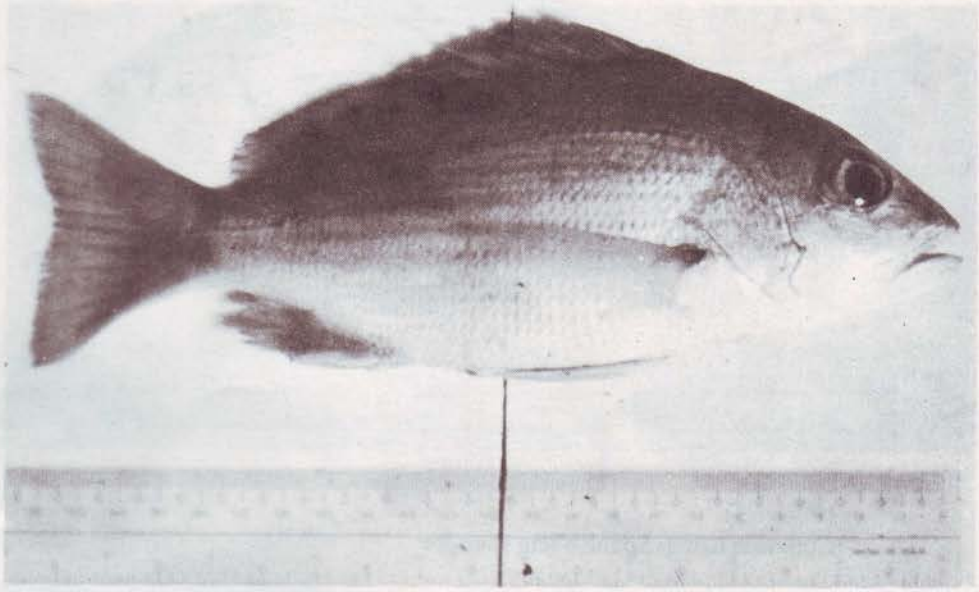


(Figure 1)
Common name : mangrove red snapper

Description: Body moderately deep. Snout somewhat pointed; preopercular notch and knob poorly developed; vomerine tooth patch crescentic; tongue with a patch of granular

teeth. Caudal fin emarginate to truncate. Color: back and sides greenish-brown; belly silvery or whitish.

2. *Lutjanus boutton* (Lacepede, 1803)
Synonym: Lutjanus caeruleovittatus (Masuda et al., 1984)

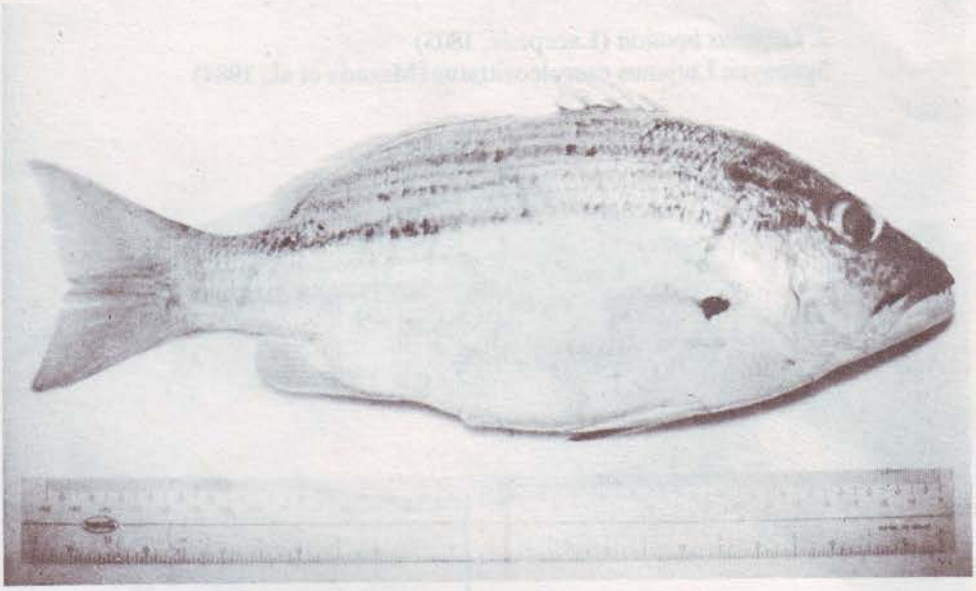


Specimen: 180 mm SL; Fishing Port, January 1991
(Figure 2)
Common name: Moluccan snapper

Description: Body moderately deep. Snout somewhat pointed; preopercular notch and knob well developed; vomerine tooth patch crescentic without a medial posterior extension; tongue smooth without teeth. Caudal fin emarginate. Color: back and sides pink or reddish; back and underside of head white or silvery-white; usually 10-12 faint yellow stripes on side; fins yellowish.

Source: Guimaras Island

3. *Lutjanus carponotatus* (Richardson, 1842)
Specimen: 260 mm SL; Fishing Port, August 1990

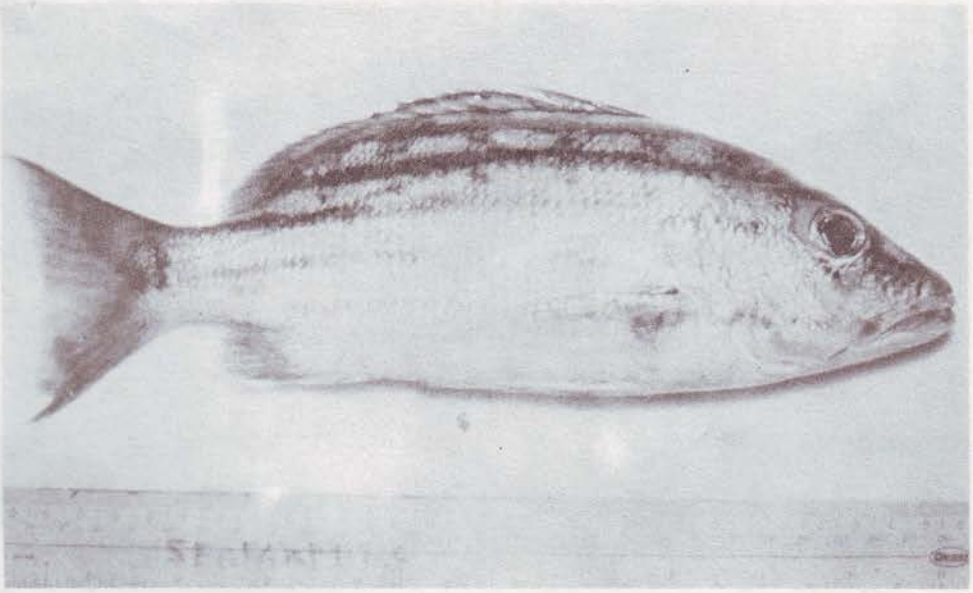


(Figure 3)
Common name: Spanish flag snapper

Description: Body moderately deep. Snout somewhat pointed; dorsal profile of head steeply sloped; preopercular notch and knob poorly developed; vomerine tooth patch triangular with medial posterior extension or diamond shaped; tongue with a patch of granular teeth. Caudal fin emarginate. Color: back and upper sides brownish; lower sides and belly yellow-white; 8-9 orange or yellow stripes on sides; pectoral fin with distinct black spot at base; fins yellowish.

Source: Roxas and Concepcion, Panay

4. *Lutjanus decussatus* (Cuvier, 1828)
Specimen: 230 mm SL; Fishing Port, July 1990

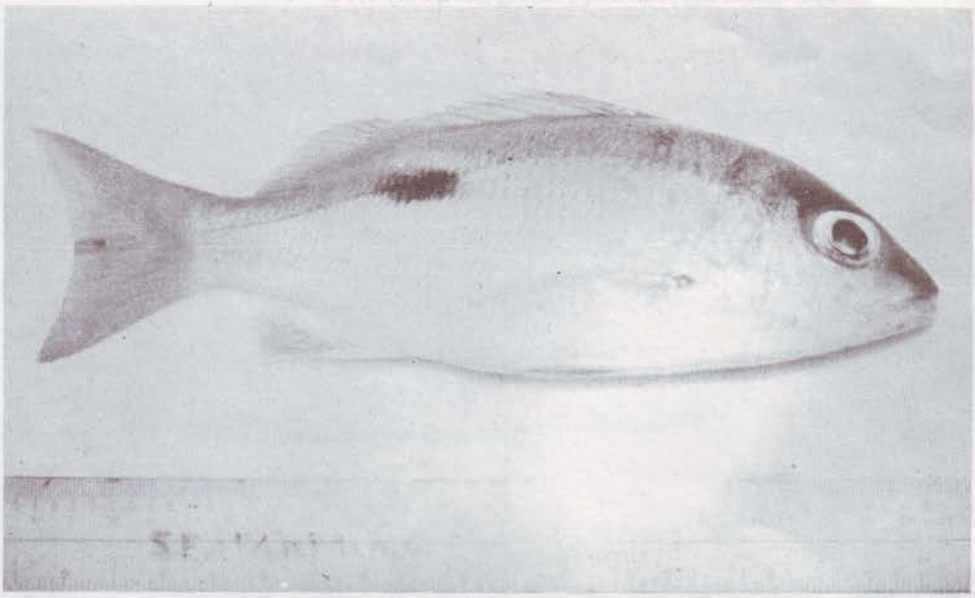


(Figure 4)
Common name: checkered snapper

Description: Body moderately deep. Dorsal profile of head moderately sloped; preopercular notch and knob well developed; vomerine tooth patch crescentic without medial posterior extension; tongue with a patch of granular teeth. Caudal fin emarginate; posterior profile of dorsal and anal fins rounded. Color: generally whitish with a "checkerboard" pattern on upper half of sides (dark brown bars and stripes surrounding rectangular, whitish windows); lower half of sides with 2 dark brown stripes; black spot covering base of caudal fin.

Source: Guimaras Island

5. *Lutjanus fulviflamma* (Forsskal, 1775)
Specimen: 190 mm SL; Fishing Port, July 1990



(Figure 5)
Common name: blackspot snapper

Description: Body moderately deep to slender. Dorsal profile of head moderately sloped; preopercular notch and knob poorly developed; vomerine tooth patch triangular with medial posterior extension or diamond shaped; tongue with a patch of granular teeth. Caudal fin truncate or slightly emarginate. Color: back and upper sides light brown; lower sides whitish; belly whitish to yellow; 6-7 yellow stripes on side; prominent black spot on lateral line below base of anterior part of soft portion of dorsal fin; fins yellowish.

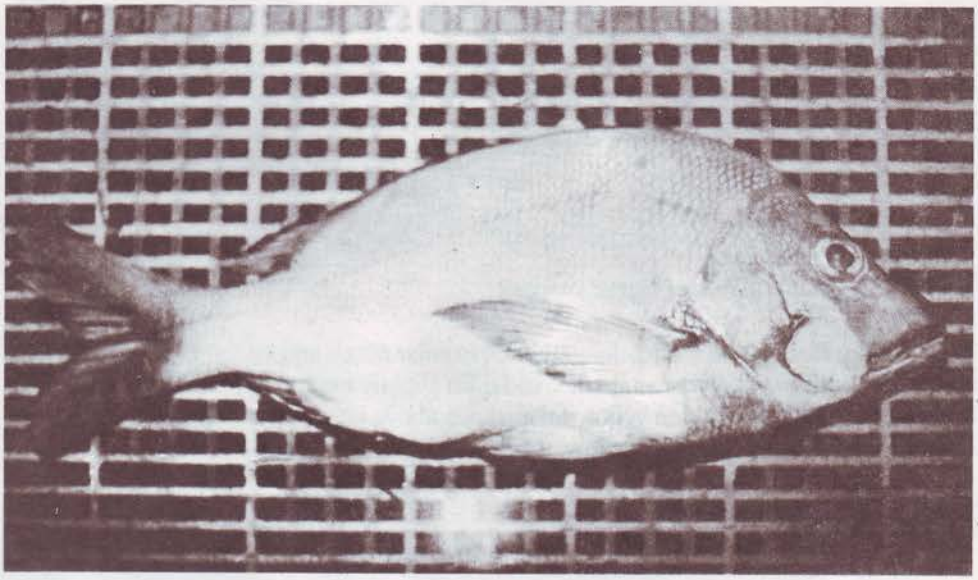
Source: Guimaras Island

6. *Lutjanus fulvus* (Schneider, 1801)
Specimen: 170 mm SL; Central Market, November 1990
Common name: blacktail snapper

Description: Dorsal profile of head steeply sloped; peropercular notch and knob well developed ; Vomerine tooth patch crescentic without medial posterior extension; tongue smooth without teeth; posterior profile of dorsal and anal fins rounded; caudal fin slightly emarginate. Color: back and sides grey to brown; belly and underside of head whitish; dorsal fin brown to reddish, with a narrow blackish band near margin, broader on soft part or dorsal. Caudal fin blackish; pelvic and anal fins yellow.

Source: Guimaras Island

7. *Lutjanus gibbus* (Forsskal, 1775)
Specimen: 190 mm SL; Central Market, November 1990

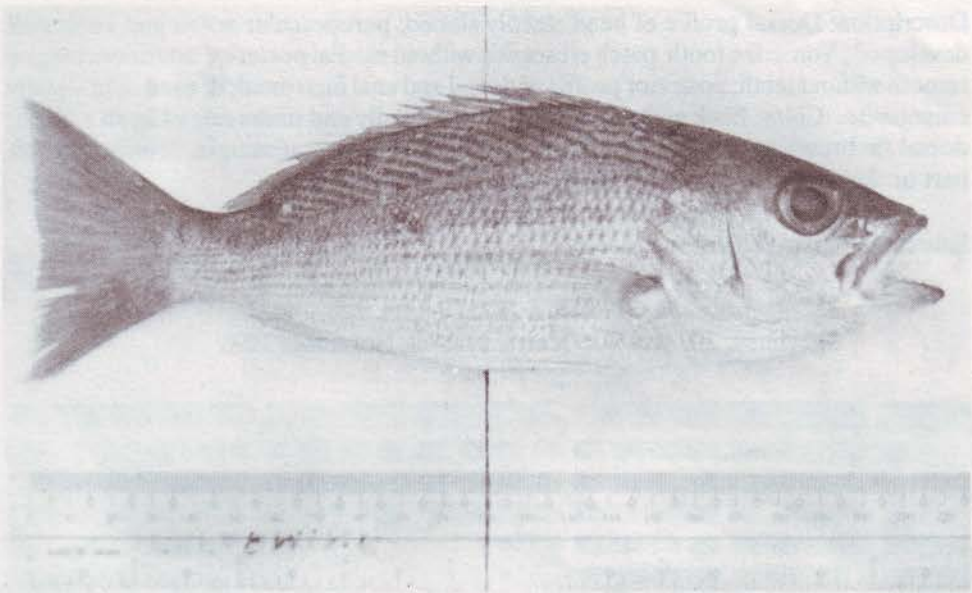


(Figure 6)
Common name: humpback red snapper

Description: Body relatively deep. Dorsal profile of head steeply sloped; preopercular notch and knob well developed; vomerine tooth patch crescentic without medial posterior extension; tongue smooth without teeth; posterior profile of dorsal and anal fins pointed. Caudal fin distinctly forked with rounded lobes (upper lobe larger than lower). Color: red; darker on upper portion of head; fins reddish to dark brown.

Source: Guimaras Island and Palawan

8. *Lutjanus lutjanus* (Bloch, 1790)
Synonym: Lutjanus lineolatus (Masuda et. al., 1984)
Specimen: 175 mm SL; Fishing Port, June 1991



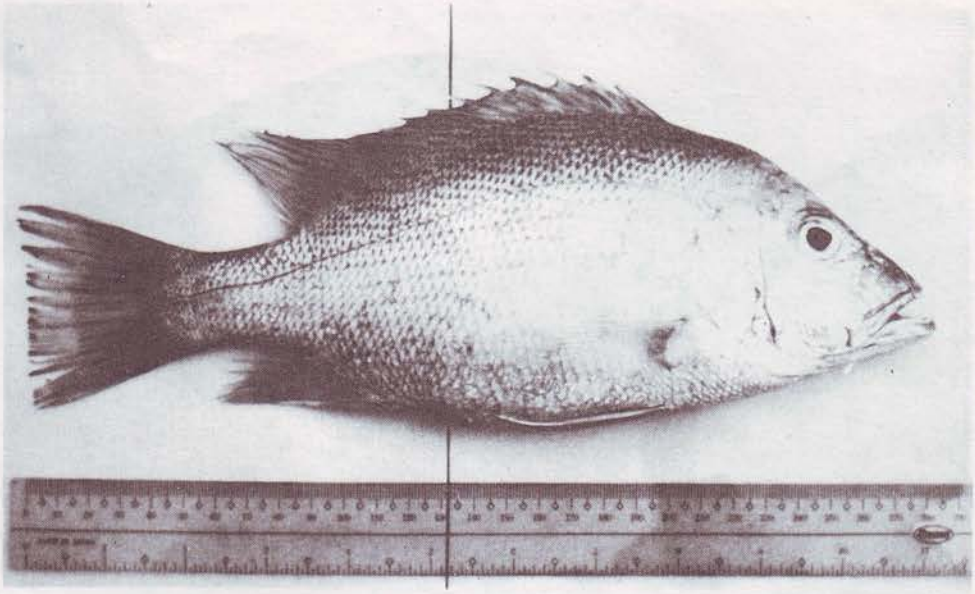
(Figure 7)
Common name: bigeye snapper

Description: Body slender and elongated. Opercular notch and knob poorly developed; vomerine tooth patch arrow shaped. Caudal fin slightly emarginate to truncate. Color: body pinkish with 5-7 golden yellow lines, those above lateral line rising obliquely; line in middle of body thicker; fins yellow.

Source: Cuyo, Palawan

9

9. *Lutjanus malabaricus* (Schneider, 1801)
Specimen: 230 mm SL; Fishing Port, September 1990

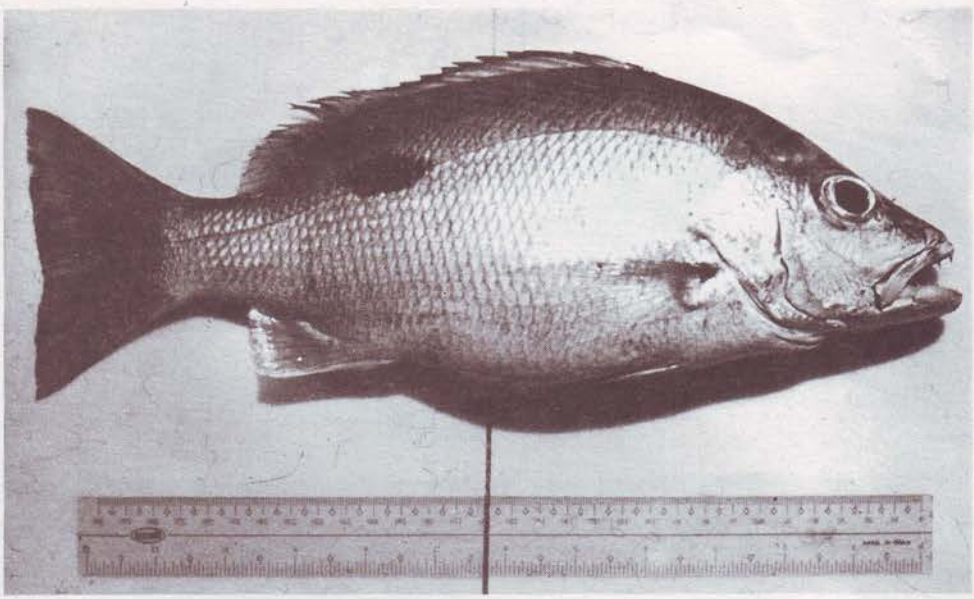


(Figure 8)
Common name: malabar red snapper

Description: Body relatively deep. Dorsal profile of head steeply sloped; preopercular notch and knob poorly developed; vomerine tooth patch crescentic or triangular without medial posterior extension; tongue smooth without teeth; posterior profile of dorsal and anal fins slightly rounded or angular. Caudal fin truncate. Color: back and sides red, lighter on lower parts; fins reddish.

Source: Palawan

10. *Lutjanus monostigma* (Cuvier, 1828)
Specimen:280 mm SL; Central Market, April 1991

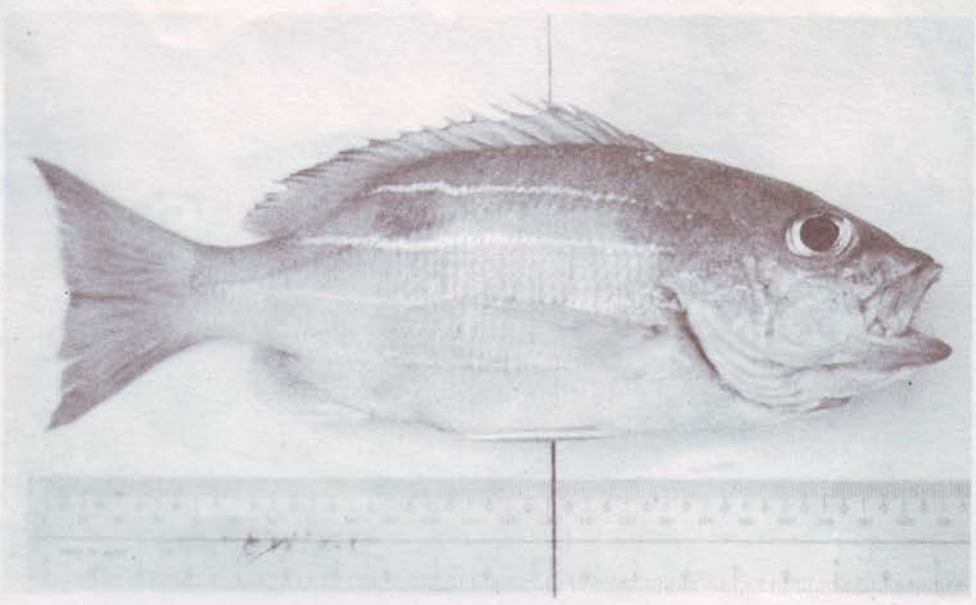


(Figure 9)
Common name: one-spot snapper

Description: Body moderately deep and slender. Dorsal profile of head gently sloping; preopercular notch and knob poorly developed; vomerine tooth patch crescentic. Tongue smooth without teeth. Caudal fin truncate. Color: body pinkish; brown on dorsal portion and upper part of head; black spot located below anterior part of soft dorsal rays; fins yellow.

Source: Guimaras Island

11. *Lutjanus quinquelllineatus* (Bloch, 1790)
Synonym : Lutjanus spilurus (Masuda et. al., 1984)
Specimen: 190 mm SL; Fishing Port, June 1991



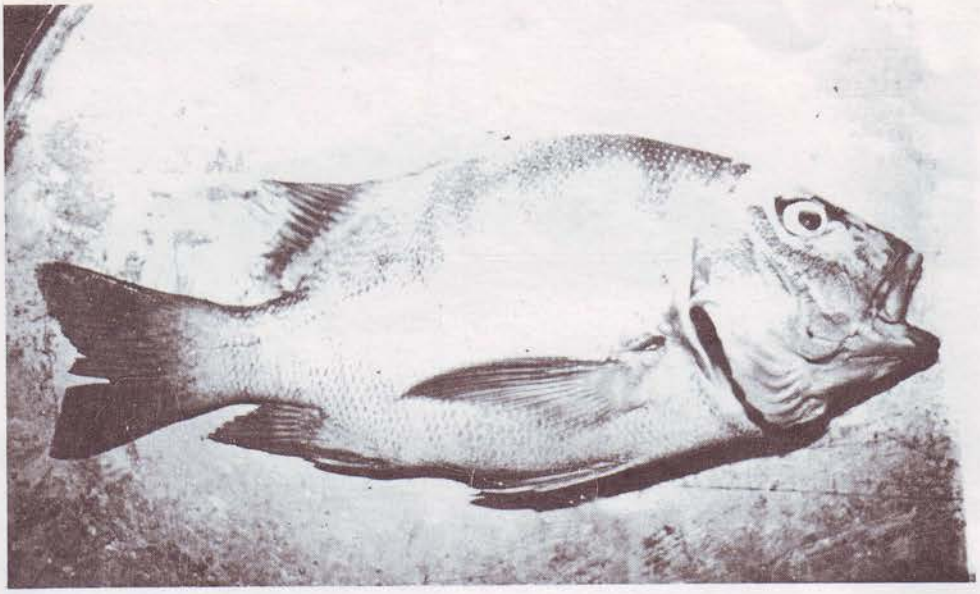
(Figure 10)
Common name: five-lined snapper

Description: Body moderately deep. Dorsal profile of head steeply sloped; preopercular notch and knob well developed; tongue smooth, without teeth; vomerine tooth patch crescentic. Posterior profile of dorsal and anal fins rounded. Caudal fin slightly emarginate. Color: head pinkish; body bright yellow with five blue stripes; black blotch located anterior to soft dorsal rays just above lateral line; fins yellow.

Source: Suyo, Palawan

12

12. *Lutjanus rivulatus* (Cuvier, 1828)
Specimen: Photo documented in Central Market, May 1991

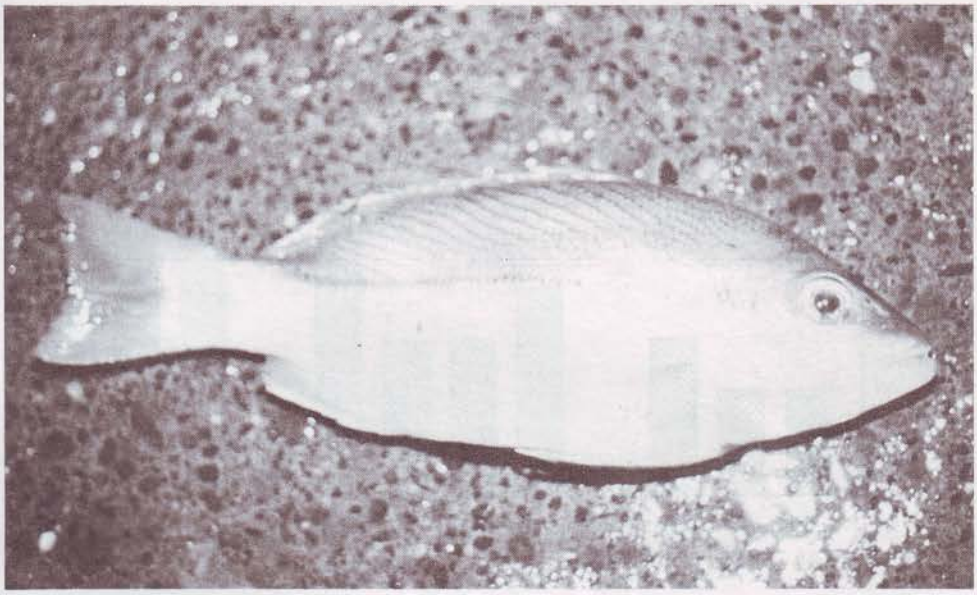


(Figure 11)
Common name: blubberlip snapper

Description: Body very deep. Dorsal profile of head steeply sloped; preopercular notch and knob moderately developed; vomerine tooth patch crescentic without medial posterior extension; tongue smooth without teeth; posterior profile of dorsal fin rounded; posterior profile of anal fin distinctly pointed. Caudal fin truncate or slightly emarginate. Color: generally brown; each scale on side with a pale brown border; head with numerous undulating blue lines; lips tan; fins yellowish to dusky grey-brown.

Source:Guimaras Island

13. *Lutjanus vitta* (Quoy and Gaimard, 1824)
Specimen 230 mm SL; Fishing Port, August 1990



(Figure 12)
Common name: Brownstripe snapper

Description: Body moderately deep to relatively slender. Dorsal profile of head moderately sloped; preopercular notch and knob poorly developed; vomerine tooth patch triangular with medial posterior extension or diamond shaped; tongue with a patch of granular teeth. Caudal fin slightly emarginate or truncate. Color: back and upper sides brown, lower sides and belly whitish or pink; narrow longitudinal brown lines on sides, those above lateral line slanted posteriorly toward dorsal fin base; a dark brown or blackish stripe along middle of side from eye to upper half of caudal peduncle; fins yellow except pelvics whitish.

Source: Roxas and Concepcion, Panay

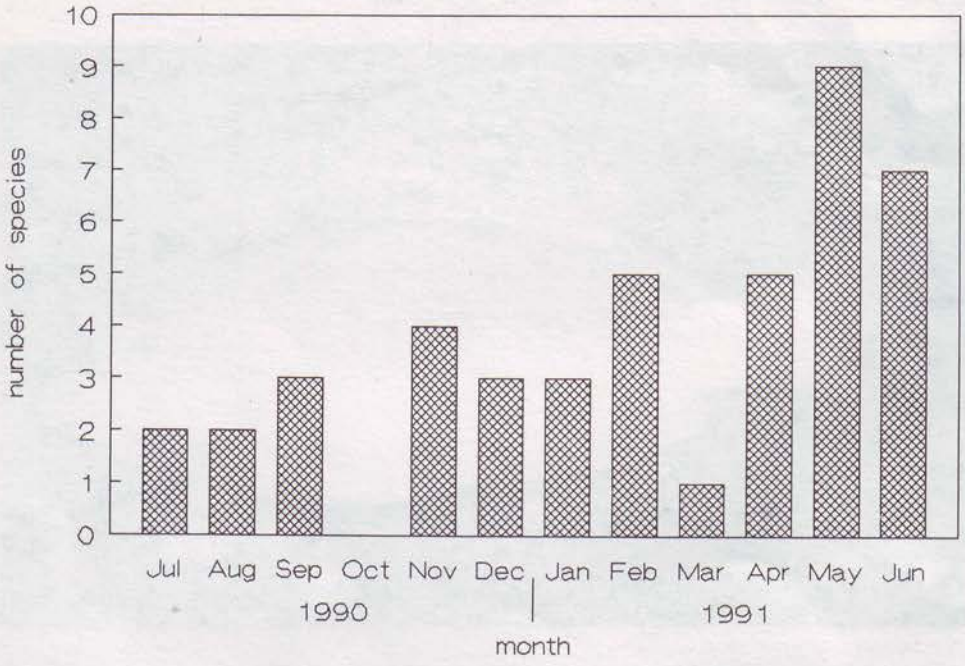


Figure 13 shows the number of lutjanid species that were observed each month in both the Iloilo Fishing Port and Central Market. Although lutjanids were present year round, it can be seen that the number of species increased in April with a peak in May. The high number of species that occurred during this time may be the result of the spawning season as stated by Allen (1985). The incidence of snapper throughout the year may serve as a guide for availability of species in the world. The three most abundant and commonly observed species were *Lutjanus vitta, Lutjanus gibbus* and *Lutjanus argentimaculatus*.

This study serves as a preliminary investigation to identify the species of lutjanids caught from Panay and Palawan Island waters. Location of capture should be verified by field surveys. It should also be noted that high value species such as *Lutjanus malabaricus* were not captured in waters off Panay but reportedly near Palawan.

ACKNOWLEDGEMENT

The authors wish to thank Prof. Prudencia Conclu of the College of Fisheries, University of the Philippines in the Visayas for verifying the specimens.

LITERATURE CITED

Allen G.R. 1985. FAO species catalogue. Vol. 6. Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. FAO Fish. Synop., (125) Vol. 6: 208p.

Cheong, L. 1988. Aquaculture development in Singapore. Pages 117-128 in J.V. Juario and L.V. Benitez, eds. Perspectives in aquaculture development in Asia and Japan, Southeast Asian Fisheries Development Center (SEAFDEC), Tigbauan, Philippines.

FAO, 1990. Regional seafarming resources atlasss. FAO/UNDP Regional Seafarming Development and Demonstration Project. RAS/86/024.

Herre, A.W. 1953. Check list of Philippine fishes. Fish and Wildlife Service, U.S. Dept. Int., Res. Rep., 20:1-977.

Lee, S.C. 1987. Fishes of the family Lutjanidae of Taiwan. Bull. Inst. Zoology, Academia Sinica 26 (4): 279-303.

Masuda, H., Amaoka K., Araga C., Uyeno T. and Y. Yoshina. 1984. The fishes of the Japanese archipelago. Tolai Univ. Press, Tokyo, Japan. 2 Vol.

PURIFICATION AND CHARACTERIZATION OF HYPAPHORINE FROM THE SEEDS OF ERYTHRINA VARIEGATA L. VAR. PHILIPPINENSIS (LINN.) MERR. FAM. LEGUMINOSAE[2]

JOSEFINA B. MANALO, BYUNG HOON HAN,
MYUNG HWAN PARK and RIZALINA B. SANTOS

ABSTRACT

The crude alkaloidal crystals obtained from the seeds of Erythrina variegata L. var. Philippinensis (Linn.) Merr. were further purified, the identity and structure established as hypaphorine by correlating the various spectral data and the chemical tests obtained.

INTRODUCTION

The genus Erythrina (Leguminosae) has been the subject of chemical investigation by some workers (Marañon, et.al., 1932, Romeo et.al., 1965, Barakat, et. al., 1977). They have shown the presence of a number of alkaloids and their properties alledge to be identical with those isolated from other species, yet no spectral data to support this has been reported yet. For this reason, this paper reports on the characterization of the purified compound from the seeds of *Erythrina variegata* Linn. var. Philippinensis and establishes its chemical structure. This part of the study has been undertaken at the Natural Products Research Institute, Seoul National University, in Seoul, Korea.

EXPERIMENTAL

Isolation of the crude alkaloid

Isolation of the crude alkaloid from the seeds of E. variegata L. Var. Philippinensis (L.) Merr. has been done at the University of the Philippines, College of Pharmacy as shown in Scheme I (Santos, R.B., et. al., 1981).

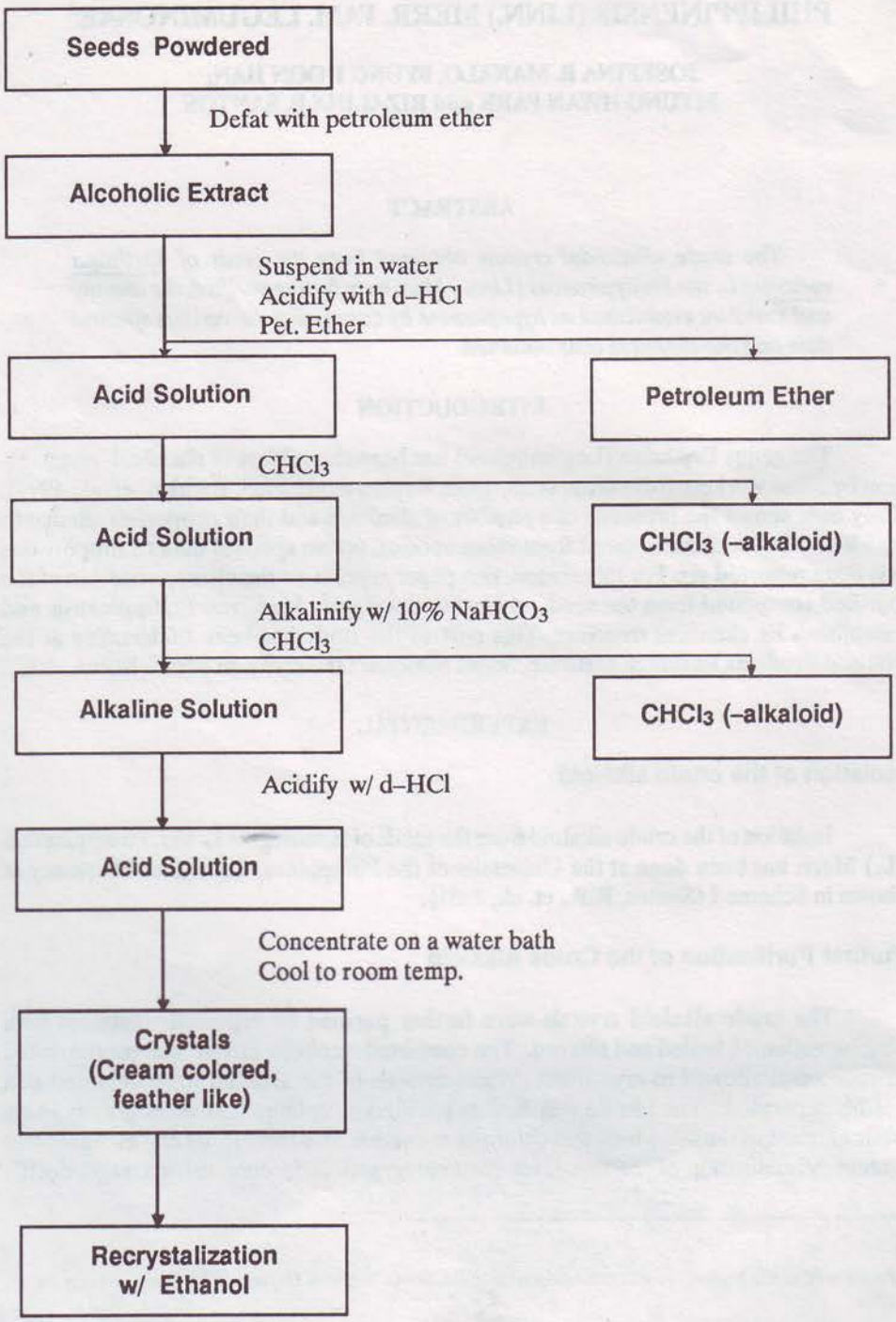
Further Purification of the Crude Alkaloid

The crude alkaloid crystals were further purified by repeated treatment with absolute ethanol, boiled and filtered. The combined alcoholic filtrate was concentrated in vacuo and allowed to crystallize. White crystals of the alkaloid were obtained and readily separated. The filtrate was further purified by column chromatography using basic alumina as the adsorbent and chloroform-methanol-water (15:10:2.5) as the solvent system. Visualization of the thin-layer chromatograms were done using Dragendorff's

---

2 Paper read at the Natural Products Research Institute, Seoul National University Seminar, January 14, 1983

SCHEME 1. ISOLATION OF HYPAPHORINE



reagent. The fractions with essentially identical TLC patterns and Rf value were combined, concentrated in vacuo and recrystallized with ethanol. Mp of the purified crystal was 222-224^0.

Chemical Tests for the Alkaloidal Crystal

The following confirmatory test on the isolated compound were undertaken:

1. N-test - A small amount of sample was taken and placed in an open ampule. Add metallic sodium. Heat until sample and Na (metal) have completely reacted (carbonized). Immerse the heated ampule containing the reacted sample to a test tube containing distilled water (Ca 3 - 5 cc). Filter, to the filtrate add freshly prepared $FeCl_2$ solution. A greenish-blue color indicates positive test for N.

2. Methylation with Diazomethane reagent - (For the presence of COOH) - To a small amount of sample add a small volume of Diazomethane reagent. Set aside for 3-4 hours. TLC.

3. Hydrazinolysis - (Test for the presence of $COOCH_3$) A small amount of sample is placed in a test tube and about 0.2 ml of hydrazine hydrate is added. The mixture is heated in an alcohol lamp to boiling.

4. Acetylation - A small amount of sample is mixed with about 0.5 ml of pyridine and 0.5 ml of acetic anhydride mixture. The mixture is made to stand overnight. One half of this mixture was placed on a test tube and dried using N. gas. The residue obtained is dissolved in a few drops of methanol. TLC, visualizing agent is Dragendorff's reagent. (To test compounds possessing primary or secondary free amino or hydroxyl groups).

5. –Ninhydrin test - (Test for primary amino group). The sample and control is spotted in a prepared TLC plate. The plate is sprayed with ninhydrin solution and heated for 2 - 3 minutes at 80^{o}C.

6. Ehrlich's test - (Test for Indole Alkaloids). Prepare Ehrlich's reagent. (10% p-dimethyl-amino-benzaldehyde in concentrated HCl). Mix 1 part 10% p-dimethyl-amino-benzaldehyde + HCl with 4 parts acetone just before use.

Dip a pre-coated TLC plate as soon as reagent is prepared. Hold plate flat on table covered with white sheets and flow off the acetone. Observe colors produced.

Free base preparation of the alkaloid

The equivalent molar mixture of the alkaloid (HCl salt) and $NaHCO_3$, were dissolved in small amount of water and then CO_2 gas was formed. The reaction mixture was concentrated to dried residues and recrystallized with ethanol.

Instrumental analysis

All melting points were taken on a heat block apparatus and given uncorrected values.

Recording spectrophotometer, Gilford type 2600 was used for the measurements of UV-visible absorption spectra, PMR spectra were obtained in D_2O solution using TMS as internal standard on Perkin-Elmer NMR Spectrometer (90MHZ) and recorded by δ ppm.

IR spectra were determined in KBr pellets on Perkin-Elmer type 283 B Spectrophotometer.

RESULTS AND DISCUSSION

Thin-layer chromatography of the purified crystalline compound isolated by column chromatography had an Rf value of 0.45.

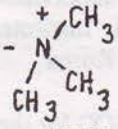
Identification of the compound

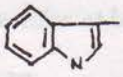
The compound gave positive results with N-test, Gragendorff's and Mayer's reagent indicative of an alkaloidal compound. It also gave positive results with Ehrich's reagent which suggests that the compound is an indole alkaloid. With ninhydrin, however, it gave a negative results. This suggests that the compound does not have a primary amino group.

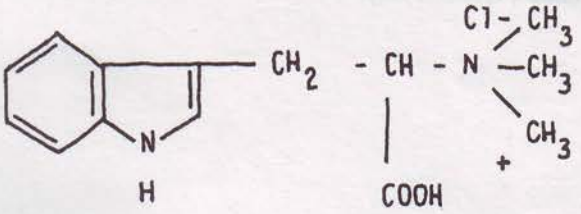
IR spectrum (Figure 1) showed the band at 3420 cm^{-1} suggesting the presence of an amino group. The absorption band at 1725 cm^{-1} indicates a carboxylic acid group, also, α -halogen present at said wavenumber raises the frequency of V(C=0). The bands arising at 3040, 3020, V (C = C), 1618 and 1550 cm^{-1} V(c=c) arromaticity. Enhancement of intentsity in the 1370 cm_{-1} band (δ (C-H) for CH_3) is common when methyl groups are attached to N. The wavenumber at 743 indicates an indole ring.

In PMR spectrum (Figure 1) the compound displays seventeen hydrogens.

D_2O

δ ppm; 3.65 (3 x 3H, s,  ; 3.82 – 3.63 (2H, m, – CH_2);

4.66 – 4.38 (1H – CH-); and 7.55 – 8.18 (5H, ). These properties of the compund give the following structure:



Hypaphorine

ACKNOWLEDGEMENT

I am very grateful to Dr. Byung Hoon Han and his associates, Dr.Y. Han and Mr. M.H. Park for their very valuable information and supervision in the conduct of the research work which has been undertaken in their Institute, the Natural Products Research Institute, Seoul National Unversity, Seoul, Korea.

I am also very pleased to acknowledge UNESCO for the training accorded me.

REFERENCES

Marañon, J. 1932. Phil. Jour. of Science, Vol. 48, No. 4, p. 563-580, 6 plates

Romeo, John T. and E.A. Bell-Lloydia, Vol. 37, No. 4,p. 543-568, 1965.

Barakat, I., Jackson, A.A.; Abdulla, M.I. Lloydia. 1977. 40 (5), 471 - 5 (Eng.).

Santos, R.B. et. al. 1981. "Screening of Philippine Plants", College of Pharmacy, University of the Philippines, Quezon City.

FIGURE -1 INFRARED SPECTRUM OF HYPAPHORINE

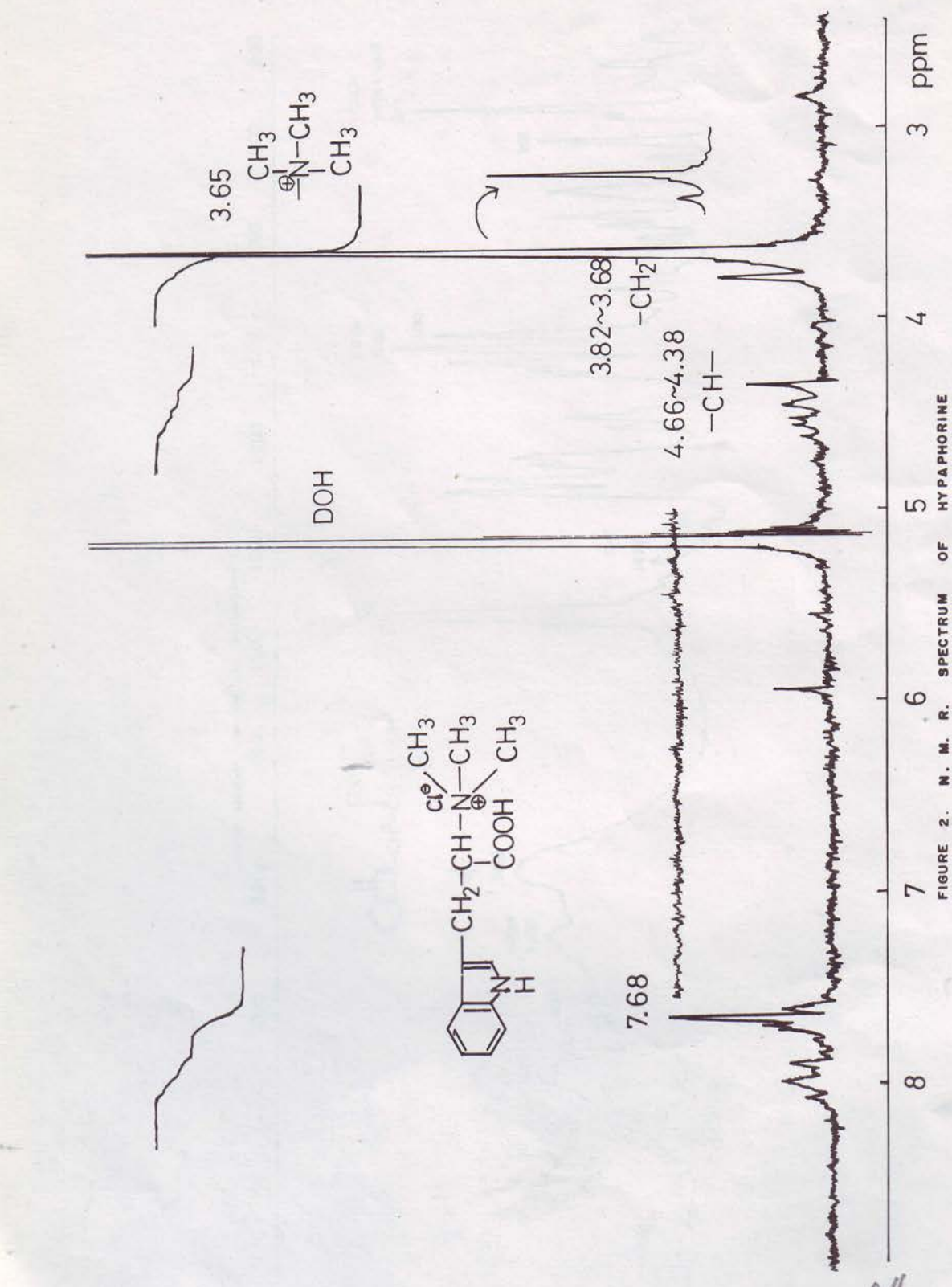


FIGURE 2. N. M. R. SPECTRUM OF HYPAPHORINE

INHIBITORY EFFECTS OF FREE GLUTAMATE, GUANOSINE MONOPHOSPHATE, INOSINE MONOPHOSPHATE AND A FLAVOUR ENHANCER ON BONE MARROW GENOTOXICITY OF DIMETHYLNITROSAMINE

CLARA Y. LIM-SYLIANCO, L. SYLIANCO-WU and M.V. BOTUYAN
Institute of Chemistry, College of Science
University of the Philippines, Diliman, Quezon City

ABSTRACT

Based on the results of the micronucleus test, glutamic acid, guanosine monophosphate and inosine monophosphate and a flavour enhancer containing these two nucleotides and glutamic acid did not exhibit mutagenic and clastogenic activity to bone marrow cells of experimental mice. However, these substances showed antigenotoxic activity against dimethylnitrosamine, a mutagen and a carcinogen.

INTRODUCTION

It has been shown that glutamate added to food potentiates the flavour of food. This effect of glutamate is not a consequence of enhancement of primary tastes in food but the potentiation is brought about by synergistic action with nucleotides contained in foods (Yamaguchi and Kimizuka, 1979). This synergism is attributed to enhance binding of glutamate to the receptors in the presence of mononucleotides (Torii and Cagase, 1980). Glutamic acid and each of five other amino acids have been reported to reduce the genotoxicity of mutagenic anticancer agents (Lim-Sylianco and Guevara, 1989). In this study, antigenotoxic activity of free glutamate, guanosine monophosphate (GMP), inosine monophosphate (IMP) and a flavour enhancer is reported. Antigenotoxic activities were assessed using the micronucleus test (Schmid, 1975). This test is based on the finding that substances which affect the structure of DNA can also induce chromosome breaking effects. When the chromatin material of bone marrow cells are fragmented, some fragments are left behind when the red blood cells expel their nuclei after telophase. These fragments form micronuclei. The use of micronuclei frequencies as a quantitative indicator of chromosome breakage has been validated on more than 100 genotoxic and/or carcinogenic chemicals (Heddle, Benz and Countyman, 1978).

MATERIALS AND METHODS

Dimethylnitrosamine (DMN), guanosine monophosphate, inosine monophosphate and free glutamate were obtained from Sigma Chemical Company, St. Louis, Missouri. Fetal calf serum was supplied by Grand Island Biological Supply. Swiss Webster Mice were obtained from the College of Veterinary Medicine, University of the Philippines, Diliman, Quezon City.

The micronucleus test (Schmid, 1975) was used to investigate the antigenotoxic activity of free glutamate, GMP, IMP and a flavour enhancer which contains glutamate, GMP and IMP. Dimethylnitrosamine was administered twice by oral gavage (24 hours

apart). Simultaneously, either L-glutamate, GMP, IMP or a flavour enhancer containing glutamate, GMP and IMP was given also by oral gavage. Six hours after the second administration, the animal was sacrificed by cervical dislocation. The femur was removed and the bone marrow cells were flushed out using fetal calf serum. The cell suspension was centrifuged and the supernatant discarded. The cells were spread on slides, stained and examined under the microscope for micronucleated polychromatic erythrocytes.

RESULTS AND DISCUSSION

The micronucleus test allows one to figure out whether the test substance fragments the chromatin material of the bone marrow cells. It can be used to study the clastogenic or the chromosome breaking effects of genotoxic substances.

No clastogenic effects were observed of L-glutamate, GMP, IMP, and a flavour enhancer which contains monosodium glutamate and the nucleotides. The results are shown in Table 1. The number of micronucleated polychromatic erythrocytes induced was at the range of the negative control which was distilled water. A range of concentration of L-glutamate and the flavour enhancer was used. Increase in concentration did not increase the formation of micronucleated polychromatic erythrocytes. Thus, these substances did not fragment the chromatin material of the bone marrow cells of the experimental mice. These substances did not exhibit genotoxic activity.

Dimethylnitrosamine, on the other hand, induced an appreciable formation of micronucleated polychromatic erythrocytes as shown in Figure 1. This is a well known genotoxin which is metabolized by liver enzymes to produce an alkylating species of DNA (Miller, 1964). Dimethylnitrosamine is a well known mutagen and carcinogen. When L-glutamate, GMP, IMP and a flavour enhancer was each administered simultaneously with DMN, the formation of micronucleated polychromatic erythrocytes was greatly reduced. The flavour enhancer which contains monosodium glutamate, GMP and IMP, exhibited the best reduction of the genotoxic activity of dimethylnitrosamine.

Figure 2 reveals a slight improvement in the antigenotoxic activity of L-glutamate, GMP, IMP and the flavour enhancer when the concentration was doubled.

CONCLUSION

The chromosome breaking effects of dimethylnitrosamine was greatly reduced by glutamic acid, guanosine monophosphate, inosine monophosphate and a flavour enhancer containing monosodium glutamate, guanosine monophosphate and inosine monophosphate.

LITERATURE CITED

Heddle, J.A., Benz, R.D. and Countyman, P.I. Measurement of chromosomal breakage in cultured cells by the micronucleus technique. In Mutagen-induced chromosomal damages in man. Ed. H.J. Evans and Lloyd, D.C. Edinburgh University Press. 191-234; 1978.

Lim-Sylianco, C.Y. and Guevara, A.P. Antigenotoxic effects of some amino acids. Trans. Natl. Acad. Sci. and Tech. 11: 233-242; 1989.Miller, E.C. Comments on Chemistry of Cycads. Fed. Proc. 23: 1361-1362; 1964.

Schmid, W. The micronucleus test for cytogenetic analysis. Mutation Research. 31: 31-53; 1975.

Torii, K. and Cagase, R.H. Synergism between glutamic acid and 5'mononucleotides. Biochem. and Biophys. Acta. 627: 313-323; 1980.

Yamaguchi, K. and Kimizuka, L. Glutamic Acid in Advances in Biochemistry and Physiology. Ed. L.F. Fites, S. Gavaltini, M.R. Kase, A.R. Reynolds and R.J. Wurtman. Raven Press, N.Y. 35-54; 1979.

Table 1 Lack of Mutagenic and Clastogenic Activity of Free Glutamic Acid, Guanosine Monophosphate (GMP) and Inosine Monophosphate (IMP)

TEST SUBSTANCE	CODE	Concentration mg/kg	No. Micronucleated Polychromatic Erythrocytes Per Thousand ± S.D.
Positive control,DMN (Dimethylnitrosamine)	+C	10.00 mg/kg	12.84 ± 1.33
Negative control, Distilled water	–C		0.83 ± 0.12
L-Glutamic acid	L-Glu	1.00 mg/kg 5.00 mg/kg 10.00 mg/kg 15.00 mg/kg 25.00 mg/kg 50.00 mg/kg	0.78 ± 0.05 0.68 ± 0.07 0.56 ± 0.08 0.53 ± 0.06 0.47 ± 0.09 0.43 ± 0.05
Guanosine Monophosphate	GMP	25.00 mg/kg 50.00 mg/kg	0.44 ± 0.05 0.33 ± 0.06
Inosine Monophosphate	IMP	25.00 mg/kg 50.00 mg/kg	0.47 ± 0.05 0.44 ± 0.07
L-Glu + GMP	L-GLU+GMP	25.00 +25.00 50.00 +25.00	0.34 ± 0.08 0.37 ± 0.05
L-Glu + IMP	L-Glu+IMP	25.00 +25.00 50.00 +25.00	0.42 ± 0.06 0.38 ± 0.04
Flavour Enhancer	Flvr	1.00 mg/kg 5.00 mg/kg 10.00 mg/kg 15.00 mg/kg 25.00 mg/kg 50.00 mg/kg	0.62 ± 0.09 0.51 ± 0.05 0.44 ± 0.06 0.42 ± 0.04 0.38 ± 0.03 0.35 ± 0.05

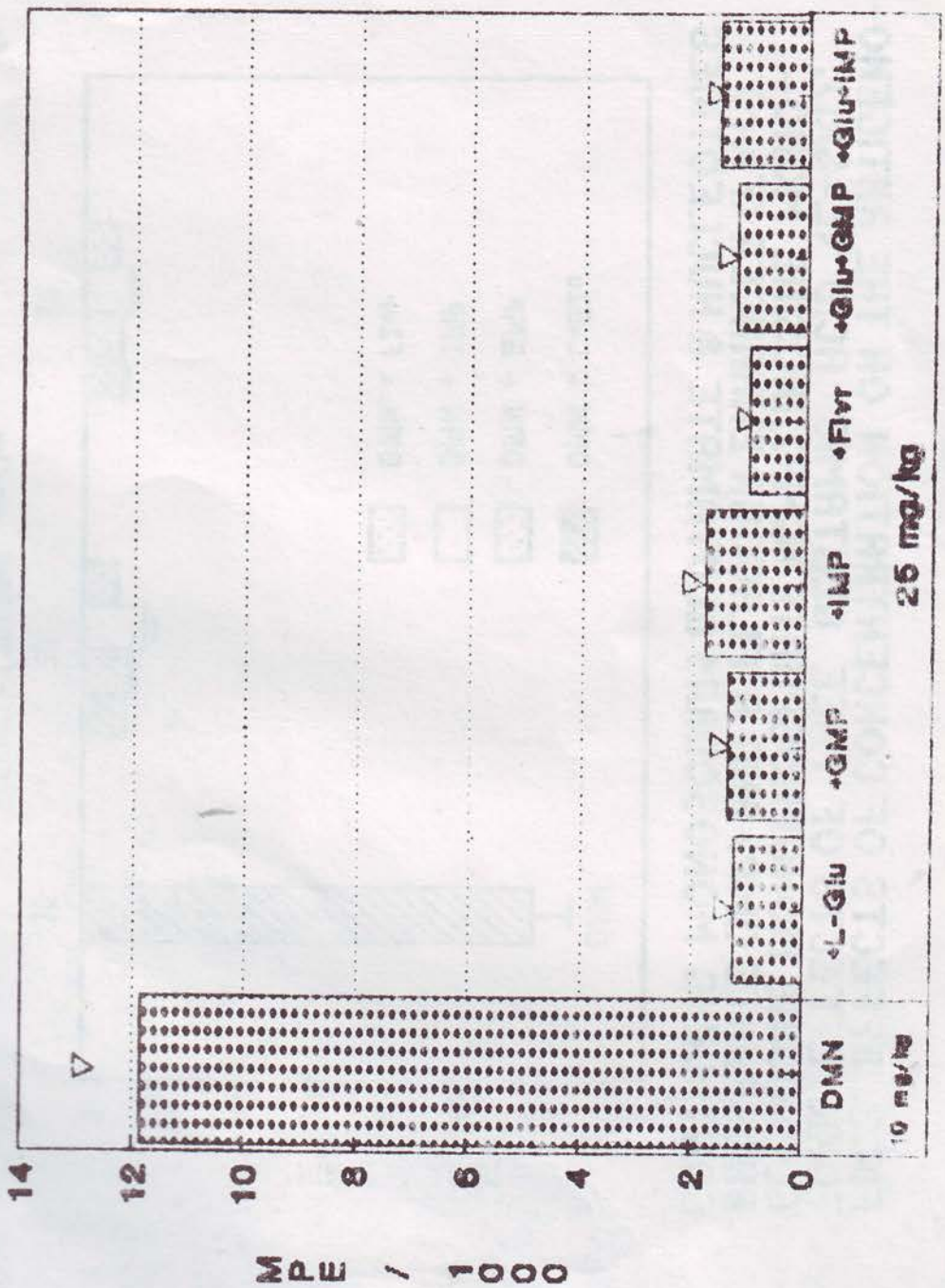
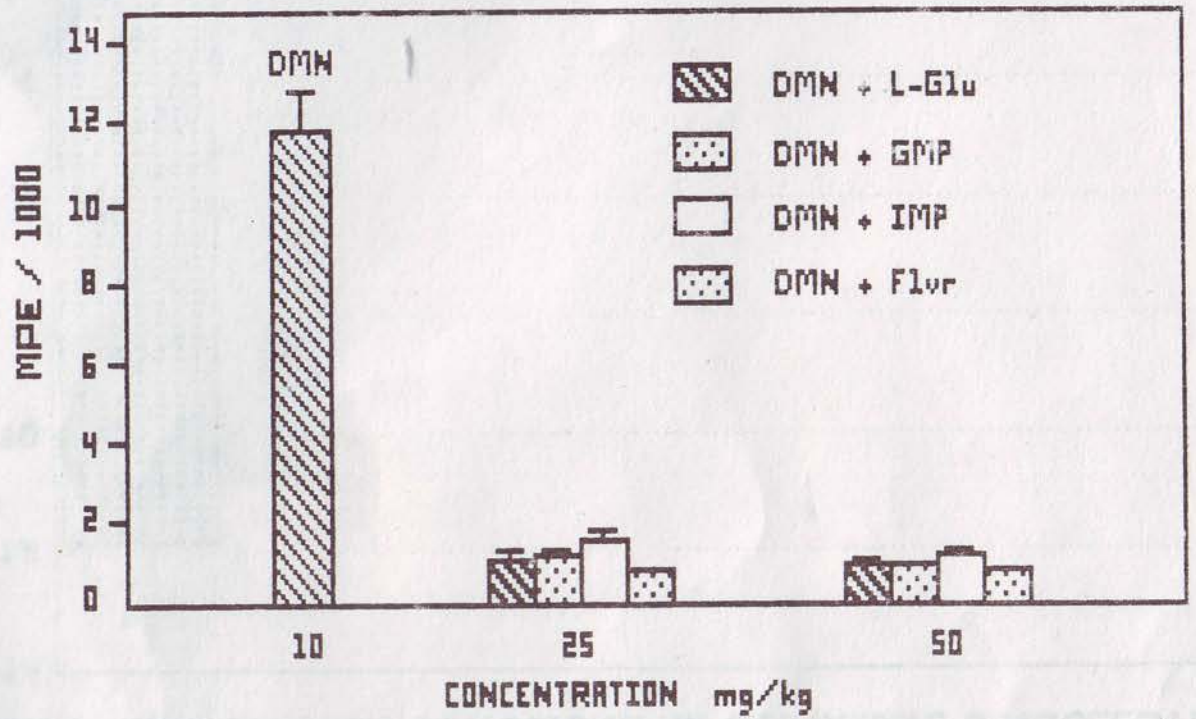


FIG.1. ANTIGENOTOXIC EFFECTS OF FREE GLUTAMIC ACID (L-Glu), GMP (GUANOSINE MONOPHOSPHATE), IMP (INOSINE MONOPHOSPHATE) AND A FLAVOR ENHANCER (Flvr) CONTAINING Na GLUTAMATE & NUCLEOTIDES

FIG.2. EFFECTS OF CONCENTRATION ON THE ANTIGENOTOXIC EFFECTS OF FREE GLUTAMIC ACID (L-Glu), GUANOSINE MONOPHOSPHATE (GMP), INOSINE MONOPHOSPHATE (IMP) AND A FLAVOUR ENHANCER (Flvr) CONTAINING MONOSODIUM GLUTAMATE & NUCLEOTIDES



PRODUCTION OF HIGH QUALITY ADSORBENT CHARCOAL FROM PHIL. WOODS II. GRANULATED ACTIVATED CARBON

V.P. ARIDA, O.G. ATIENZA, T.A. QUILAO, A.R. CABALLERO, J.S. LAXAMANA, D.L. PUGAL and C.P. GUCE
Chemical Research and Development Center National Institute of Science and Technology Bicutan, Taguig, Metro Manila, Philippines

ABSTRACT

Two Philippine wood species out of twelve earlier studied in Part I namely "ipil-ipil" Leucaena leucocephala (Lann) de Wit and coconut coir dust were selected for the production of good quality granulated activated carbon. Fluidization method was used in the study..

The conditions for the granulation of the carbonized chars using molasses were established. An optimum ratio of 1:0.5 and 1:0.8 (char:binder) was used in the granulation process for "ipil-ipil" and coir dust, respectively. Carbonization was done at a gradually increasing temperature of 3°C/min at 600°C. Carbonized granules with particle sizes ranging from 0.5 - 2.0 mm. were used for the activation study. The produced granules were activated in an external heat type stainless steel reactor as mentioned in Part I using steam as activating agent.

The physical properties and adsorptive capacity of the activated granular products obtained at varying activation conditions were determined and correlated. Methylene blue adsorption and internal surface area obtained at varying conditions were determined and correlated. Maximum values obtained for methylene blue adsorption and internal surface area are 290 mg/g AC and 1,200 m^2/g AC at 900°C, respectively for "ipil-ipil" and 390 mg/g AC and 1,000 m^2/g AC at 850°C respectively for coir dust.

Gas adsorption tests done using benzene acetone and carbon tetrachloride for both "ipil-ipil" and coir dust activated granular char products showed that both exhibited maximum adsorbability at 900°C.

Results of the study have shown that good quality granulated activated carbon can be produced from "ipil-ipil" and coconut coir dust which find suitable applications in various adsorption processes such as organic solvent adsorption, gas adsorption, water purification, oil and sugar refining, among others.

INTRODUCTION

The Philippines is one of the countries endowed with rich natural resources. Its tropical forests have been acclaimed as one of the most valuable in the world. Its wood industry is a big dollar earner. During the logging operation, forest residues and wastes are unavoidable, such that for every 100 m^3 of log harvested, approximately 51m^3 are

91

generated. These wood materials are deemed as potential sources of quality activated carbon.

Twelve Philippine wood species including coconut coir dust were earlier studied to determine their potential as sources of activated carbon . This paper presents the results of the study on the granulation of powdered charcoals from two of the most promising ones, namely *Leucaena leucocephala (Lann) de Wit* "ipil-ipil" and coconut coir dust and the production of good quality activated char granules using molasses as binder.

Granular activated carbon is generally used for adsorption of gases and vapors while activated carbon powder is used in the purification of liquids. There is an increasing trend in the application of granulated activated carbon for liquid phase adsorption process (among which are in water purification and in the sugar and oil refining industries) because it is easy to handle and can be regenerated for reuse.

Cellulosic sources, particularly wood, yield low density products when carbonized and activated. To convert such products into mechanically strong dense carbons, granulation using a binder was employed.

This study is in consonance with our desire to expand the applications of granulated activated carbon prepared from wood and wood wastes for such purposes as water purification, vapor and gas adsorption in addition to finding use for molasses which is a by-product of many sugar refining industries in the Philippines. The immediate objective is to determine the optimum conditions for the production of granulated activated carbon from wood materials and the realization of high product yield using the fluidized bed method.

MATERIALS AND METHODS

Raw materials and Sample preparation

Two of the most promising wood sources were selected for study namely:

1) "Ipil-ipil" - Wood samples were obtained from the DOST compound in Bicutan, Taguig, Metro Manila, Philippines. Size reduction of sun dried wood chips to 0.2-2.0 mm was done using a crushing machine.

2) Coconut coir dust - This was procured from Coirflex Decorticator Co., San Pablo City, Philippines. The sample was allowed to pass through a mechanical shaker to separate coir dust with an average particle size of 0.56 mm. Moisture content was reduced from 70% to 18% by sun drying.

32

The prepared samples were carbonized at 430°C using fluidized bed reactor as discussed in Part I. (Arida et.al PJS 1987)

Methods and Analysis

Proximate analysis and physical properties of the raw materials, charcoals and activated carbon products were determined.

Most of the methods employed were in accordance with the Japan Industrial Standards (JIS) procedure or with slight modification thereof as mentioned in Part I (Arida, et.al 1987).

Adsorptive properties - methylene blue test was done on the activated granular products. Determination of gas adsorbability was done according to the procedure of Hirata (1960) as follows: Weighed quantity of sample (0.2 g) is placed in one vessel and the solvent (2 ml) in the other vessel. The two glass vessels are joined together to make a closed system. They are then placed under controlled temperatures in an air bath oven for one week each, at 15°, 20°, 25° and 30°C. The quantity of the solvent adsorbed is calculated from the increase in weight of the char granules.

Granulation Process

The various stages involved in the granulation process are shown in Figure 1. The charcoals were pulverized to 200 mesh and below (Tyler). Molasses used as binder was obtained from a local sugar refining company. Its physical and thermal balance properties were determined and compared with that obtained from Japan. It was used at a ratio of 1:0.5 and 1:0.8 for "ipil-ipil" and coir dust, respectively.

Molasses diluted with water to 50% was mixed with the pulverized charcoal. The mixture was passed through an extruder and the extrudates (1 mm φ) were subsequently passed through a disk type pelletizer at 450 rpm. The granules measuring 0.5 - 2.0 mm were then carbonized in a covered stainless steel box using a muffle furnace at a heating rate of 3°C/min until the temperature of 600°C was attained.

Activation Process

The granulated chars produced from "ipil-ipil" and coir dust were each subsequently activated using an external heat type activating apparatus. It consists of a stainless steel reactor (5cm φ) equipped with an external heater. Steam (2.5 ml H_2O/min) was allowed to passed through a high temperature oil bath to generate the required amount which was subsequently charged at the lower part of the reactor, then through the bed of charcoal at the desired temperature and reaction time.

Activation of the granulated char was done at 850°C and 900°C, respectively at a reaction time which was varied from 10 to 60 minutes.

Determination and Evaluation of Adsorptive Properties of Activated Carbon

The bulk density, internal surface area and the pore distribution of the activated char products obtained at 850° and 900°C, respectively, and at varying reaction times were each determined.

The adsorptive capacity of the obtained products was evaluated by methylene adsorption (MB) test as discussed in the previous paper and by gas adsorption test adapting Hirata's method (1960). The capacity of the products for gas adsorption using benzene (C_6H_6), acetone (CH_3COCH_3) and carbon tetrachloride (CCl_4) were each separately measured at 15°, 20°, 25° and 30°C until equilibrium of the sample with vapor was reached. The adsorptive capacity is expressed as gram solvent adsorbed per gram activated carbon.

RESULTS AND DISCUSSION

The proximate analysis and physical properties of the raw materials studied, namely "ipil-ipil" and coir dust and of their respective char products are shown in Table 1.

Data obtained from the granulation process for both materials at the established optimum conditions in Table 2 show that the yield of carbonized granules is 75% and 73%, for coir dust and ipil-ipil, respectively. The comparative physical and thermal balance analyses of local molasses and that from Japan is shown in Table 3 and Fig. 2, respectively.

Effect of Activation Time on Product Yield

Correlation of the yield of activated char granules with activation time as shown in Figure 3 reveal that there was significant loss in weight of product as activation time proceeded. More pronounced decrease in yield was noted with increasing temperature. Higher weight loss which resulted in lower yield of activated carbon product was observed in coir dust as compared to that of "ipil-ipil".

In the activation process, the reaction rate of charcoal with steam in terms of weight loss was calculated as discussed in the previous report. The value of k (apparent constant) for coir dust was twice as that obtained for "ipil-ipil" as shown below:

Activation Temp. t (°C)	k	
	Coir dust	Ipil–ipil
850	57.5×10^{-3} min^{-1}	29.48×10^{-3} min^{-1}
900	92.0×10^{-3} min^{-1}	35.93×10^{-3} min^{-1}

The above data show that coir dust char can be activated faster than that of "ipil-ipil".

Correlation of Methylene Blue (MB) Adsorptive Capacity and Internal Surface Area (S) with Reaction Time (θ)

Figures 4 and 5 show the correlation of reaction time with (MB) and (S), respectively. A gradual increase in (MB) adsorbability was noted with increasing reaction time. For coir dust, activation was more effective at lower temperatures. Results show that maximum value of 390 mg/g AC was obtained at 850°C and 30 minutes. Beyond this point, (MB) value tended to decrease. For "ipil-ipil", longer reaction time (60 min) was needed to attain the maximum value of 300 mg/g AC at 850°C.

Results of the internal surface area (S) determination also gave the same increasing trend with reaction time until a saturation point was reached. Beyond this point, an abrupt decrease in the surface area was noted. Development of increased internal surface area for "ipil-ipil" was more effective at higher temperatures. Thus, higher (S) of 1,200 m^2/g AC was obtained at 900°C for "ipil-ipil" as compared to 1,000 m^2/g AC obtained for coir dust at 850°C as shown in Figure 5.

Correlation of (MB) value and (S)

Figure 6 indicates that the (MB) value is directly proportional to the (S) for both coir dust and "ipil-ipil" activated chars. Linear lines with the same slopes which indicate good inference were obtained. At (MB) = 0, the intercept gave values of 380 m^2/g AC and 450 m^2/g AC. From the slope, the area occupied by an individual molecule on the activated products as determined had a value of 150°A^2 for both samples. An accessible area of 192°A^2 was obtained for Graphon (a non porous carbon)(Graham, 1955). These nearly similar values indicate that adsorption of MB on the obtained products is physical adsorption.

Correlation between reaction time and gas adsorptive capacity

Table 4 shows the data on the gas adsorption test that was done on the activated carbon products obtained from "ipil-ipil" and coir dust and a commercial product using three gases namely, C_6H_6, CCl_4 and CH_3COCH_3 at temperatures of 15°, 20°, 25° and 30°C, respectively.

At 25°C, correlation of each of the gases adsorbed by the activated carbon products obtained at 850°C and 900°C in terms of weight % and reaction time are shown in Figures 7,8, and 9. There was an increasing trend of gas adsorbed in the activated granule products as activation time proceeded up to a certain saturation point (Figure 7) for benzene. For carbon tetrachloride, the same trend was noted as shown in Figure 9. The curve obtained however, for activated "ipil-ipil" char at 850°C for the three gases indicated that the maximum point has not yet been attained at 60 minutes reaction time.

Based on the results of analysis and evaluation of data obtained for products with yield between 20-30% as shown in Figure 3, activated "ipil-ipil" and coir dust granule products exhibit favorable results suitable for gas adsorption applications.

Comparing the adsorptive capacity of the activated granule char products, for each gram mole of gas adsorbed at 25°C, "ipil-ipil" was 1.1 to 1.2 times more adsorptive than coir dust for acetone, 1.1-1.6 times and 1.6 times more adsorptive for CCl_4 and C_6H_6, respectively. Data on the adsorptive capacity of various activated carbon products obtained for both "ipil-ipil" and coir dust at varying temperatures using various solvents are shown in Table 4.

Correlation between gas adsorbed and internal surface area

As noted in Figures 10, 11 and 12, for both "ipil-ipil" and coir dust saturated char granules, % gas adsorbed was found to be directly proportional to the surface area. The linear figure obtained passed through the zero point in the axes. From the slope obtained, one molecular area (A^{O2}) as calculated revealed that "ipil-ipil" and coir dust exhibited almost the same adsorbability values as follows:

Sample	Solvents		
	C_6H_6 (A^{O2})	CCl_4 (A^{O2})	CH_3COCH_3 (A^{O2})
"Ipil–ipil" Coir dust	55.0	30	138
	65.0	30	131

Correlation between pore distribution and pore volume

Plotting the derivatives of volume with respect to pore radius as shown in Figure 13, the pore size distribution of the activated products obtained from "ipil-ipil" and coir dust ranges between 5°A and 15°A. The adsorption of activated carbon takes place within the pore size distribution usually ranging between 5°A and 30°A (micropore). The results obtained show that the pore size distribution is within the range of the active pore sites of activated carbon.

Correlation between bulk density and reaction time

Finally, the bulk density of each of the activated products obtained with paticle sizes ranging between 0.5 - 2.0 mm was compared with the commercial activated carbon of the same particle size range. Comparative results as shown in Figure 14 indicated that the bulk density of the activated granular char products compares favorably or is even

higher than that of the commercial product. Furthermore, results show that the bulk density of the granular char products decreases with increasing activation time and temperature.

SUMMARY AND CONCLUSION

The production of granulated activated carbon from two selected promising wood sources, namely "ipil-ipil" and coir dust, were studied.

The optimum conditions for the granulation of char using molasses as binder was determined and established at optimum ratio of 1:0.5 and 1:0.8 (char:binder) for "ipil-ipil" and coir dust, respectively. Carbonization of the granules was done at a gradual temperature increase of 3°C/min until 600°C was attained. Carbonized granules with particle size ranging between 0.5 - 2.0 mm were obtained at a yield of 73% and 75%, respectively for "ipil-ipil" and coir dust.

The activation process was done at 850°C and 900°C using an external heat type activating equipment with steam at 2.5 ml H2O/min and at reaction time which was varied from 10 to 60 minutes. There was significant loss in yield as activation time is increased.

The physical properties and adsorptive capacity of the activated granular char products were determined . The apparent constant (k) as calculated was 29.48 x 10-3 min-1 for "ipil-ipil" and 57.5 x 10-3 min-1 for coir dust at 850°C activation temperature. For activation done with product yield of 30-40%, the (MB) value and internal surface area (S) were determined with results as follows: for coir dust activated at 850°C (MB) was 390 mg/g AC and surface area was 1000 m2/g AC; for "ipil-ipil" at 900°C, (MB) value was 270 mg/g AC and (S) was 1,200 m2/g AC.

Good inference was obtained on the correlation of internal surface area with gas and methylene blue adsorbabilities. A comparison of the raw materials used revealed that coir dust activated granules exhibited higher MB adsorptive capacity but has lower internal surface area than "ipil-ipil" granules. With respect to bulk density, the products obtained from both materials compared favorably with the commercial activated carbon product used as standard.

Results of this study have shown that good quality activated granule chars can be produced from "ipil-ipil" and coir dust which find suitable applications in various adsorption processes such as organic solvents adsorption, gas adsorpion, water purification, oil and sugar refining, among others.

However, the hardness of granulated activated carbon which is not covered in this report can be subject for future study. Furthermore, the use of an inner heat type activating apparatus need to be investigated in order to obtain basic data for scale-up studies.

ACKNOWLEDGMENT

This study was made possible thru the technical cooperation of the Institute for Transfer of Industrial Technology (ITIT), with the Government Industrial Development Laboratory, Hokkaido (GIDLH), Japan and the Department of Science and Technology (DOST), Philippines.

The authors wish to express their sincerest gratitude to Messrs. K. Ishibashi, K. Niikawa, Y. Noda and H. Hosoda, GIDLH researchers for their constructive suggestions and technical assistance; to Dr. Akira Ikehata, Director, 2nd Division, GIDLH, for his valuable advice and cooperation and most of all to Dr. Felimon A. Uriarte, Jr., Director, NIST for his wholehearted support and guidance for the success of the project.

REFERENCES

Arida, V.P., O.G. Atienza, T.A. Quilao, A.R. Caballero, J. Laxamana, D. Pugal, C. Guce. Production of High Quality Adsorbent Charcoal from Philippine Woods. I. Powdered Activated Carbon, Philippine Journal of Science, 1987. Vol. 116 No. 3 pp. 255-274.

Graham, D. 1955. Characterization of Physical Adsorption Systems. Jour. Phys. Chem. v. 59 pp. 896-900.

Hirata, et.al. 1960 Chem. Eng.Journal No. 24 p. 572.

Table 1. Proximate Analysis and Physical Properties of Raw Materials and Char Products							
Samples	M (wt.%)	Ash (wt.%)	VCM (wt.%)	FC (wt.%)	S (m^2/g)	B_b (g/cc)	D_p (mm)
"Ipil-ipil" wood	11.67	1.10	74.18	13.04	–	0.17	0.25–2.0
"Ipil-ipil" char	7.75	4.30	15.98	71.94	12	0.28	–200 mesh
Coir dust	19.14	3.50	68.40	8.90	–	0.08	0.25–2.0
Coir dust char	9.07	8.60	18.54	63.76	5	0.17	–200 mesh

Where M = moisture
VCM = volatile combustible matter
FC = fixed carbon
S = internal surface area
B_b = bulk density
D_p = particle size

Table 2. Data on the granulation of powdered char at optimum conditions.		
	Coir dust	"Ipil-ipil"
Ratio (char:binder)	1:0.8	1:0.5
Bulk density of char (g/cc)	0.17	0.28
Weight of char (g)	200	300
Weight of molasses (g)	160	150
% Dilution	50	580
Weight of water (g)	80	75
% yield (carbonized granules)	75	73
Bulk density of granules (g/cc)	0.51	0.56

Table 3. Comparative analysis of molasses.		
Analysis	Molasses Source	
	Philippines	Japan
Total solids, %	64.6	86.0
Sugar content, %	18.6	16.3
Ash, %	5.0	7.2

Table 4. Data on the gas adsorptive capacity of products obtained at varying temperatures using various solvents.

Sample	C_6H_6 (g/g AC)			CCl_4 (g/g AC)			CH_3COCH_3 (G/g AC)		
	15°C	25°C	30°C	15°C	25°C	30°C	15°C	25°C	30°C
I–850–30	0.30	0.35	0.35	0.61	0.65	0.71	0.34	0.34	0.34
I–850–45	0.29	0.37	0.38	0.66	0.70	0.71	0.34	0.37	0.37
I–850–60	0.33	0.43	0.44	0.75	0.82	0.82	0.43	0.45	0.45
I–900–20	0.23	0.24	0.24	0.39	0.42	0.43	0.24	0.26	0.27
I–900–35	0.30	0.43	0.45	0.75	0.89	0.89	0.44	0.48	0.48
I–900–40	0.32	0.42	0.43	0.72	0.81	0.81	0.41	0.43	0.44
CD–850–10	0.26	0.27	0.28	0.40	0.43	0.41	0.29	0.30	0.27
CD–850–15	0.31	0.32	0.30	0.51	0.61	0.54	0.37	0.34	0.32
CD–850–20	0.35	0.38	0.34	0.57	0.71	0.67	0.42	0.38	0.36
CD–850–30	0.38	0.43	0.37	0.69	0.79	0.71	0.43	0.39	0.40
CD–850–40	0.11	0.11	0.28	0.11	0.44	0.22	0.27	0.21	0.22
CD–900–5	0.22	0.21	0.34	0.24	0.52	0.55	0.25	0.26	0.22
CD–900–10	0.30	0.31	0.34	0.31	0.60	0.54	0.30	0.34	0.27
CD–900–20	0.38	0.42	0.37	0.37	0.79	0.77	0.46	0.42	0.39
Commercial AC	0.41	0.42	0.44	0.85	0.85	0.78	–	–	–

where: I = "ipil–ipil" CD = coir dust

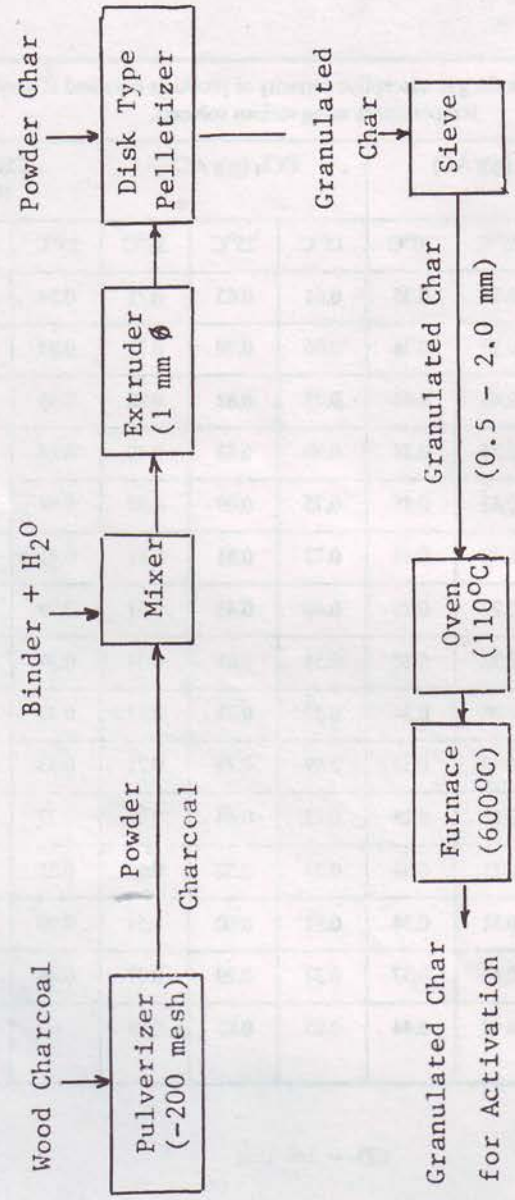


Fig. 1. Schematic diagram of granulation process for powder char.

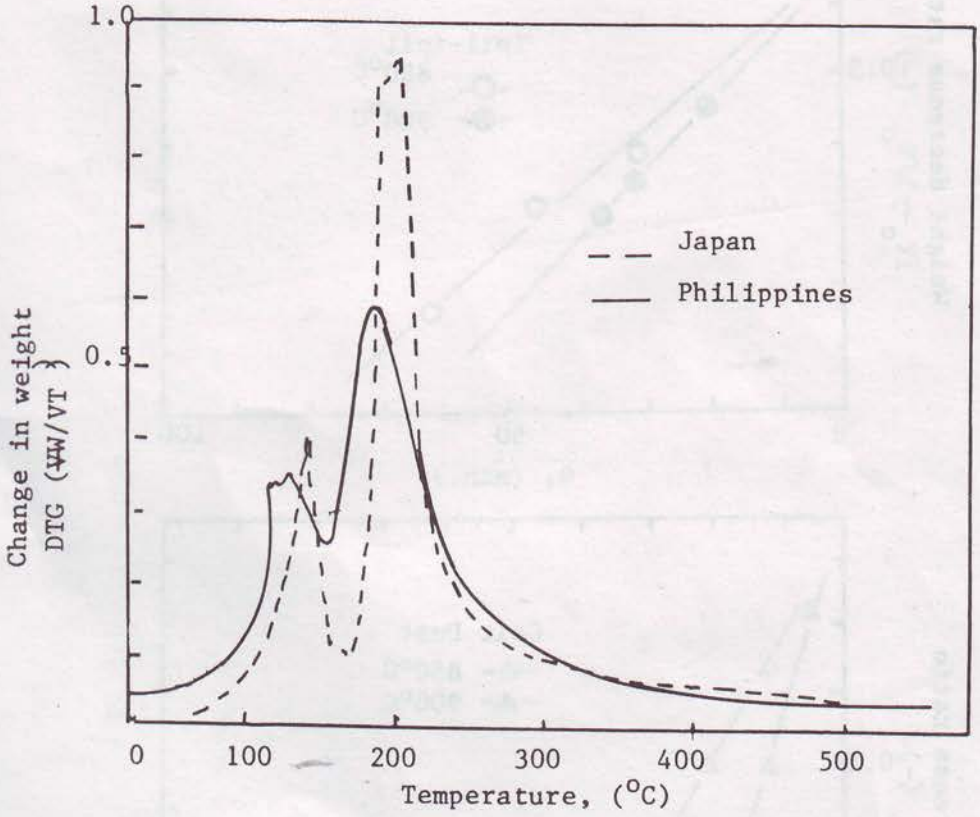


Fig. 2. Thermal balance analysis of molasses.

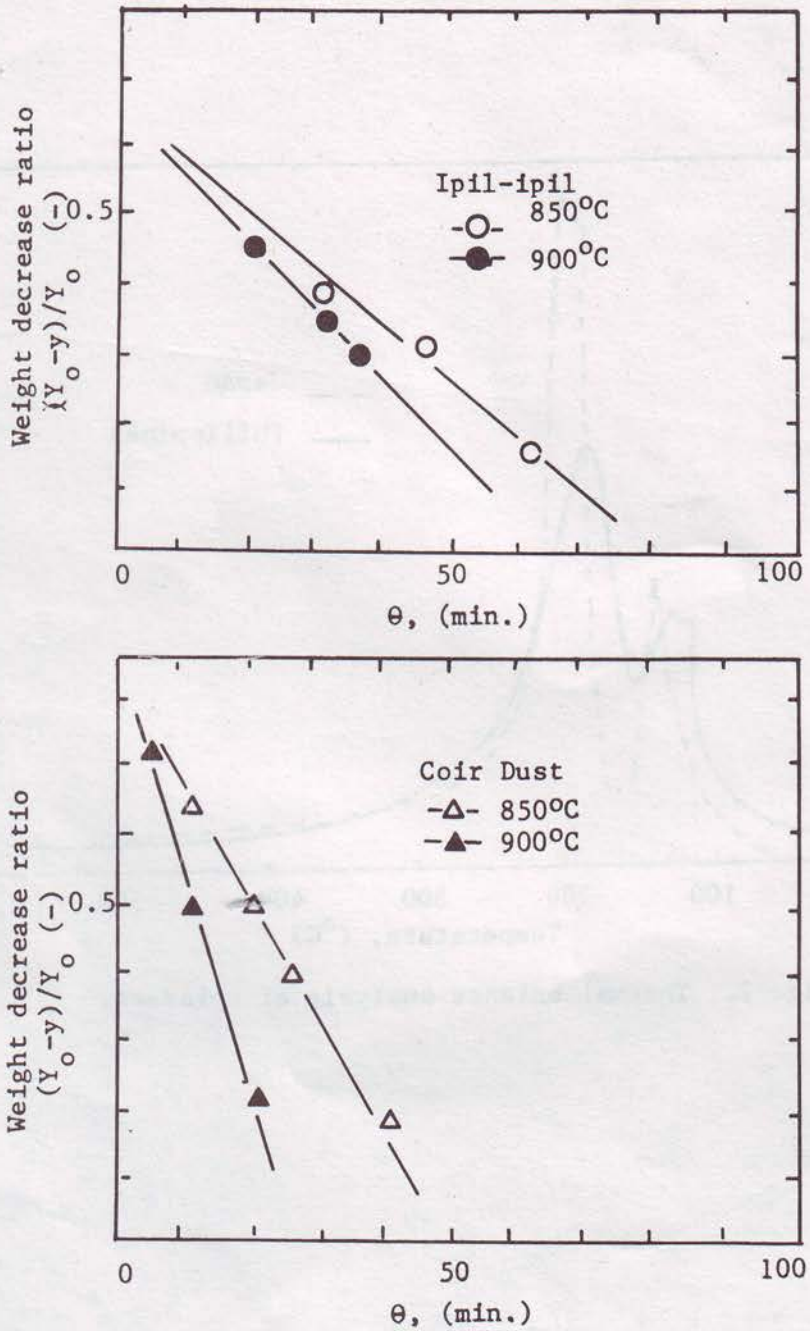


Fig. 3. Correlation between change i n weight and reaction time (θ) at various activation temperature.

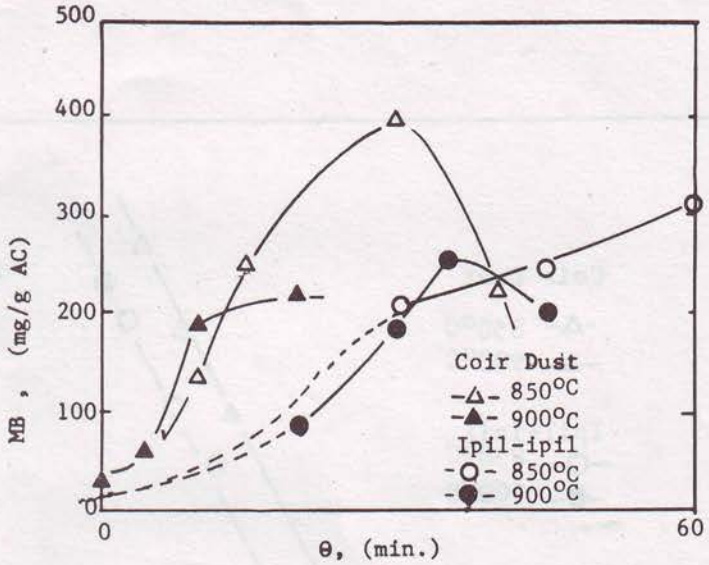


Fig. 4. Effect of reaction time (θ) on methylene blue value (MB) of the activated char products.

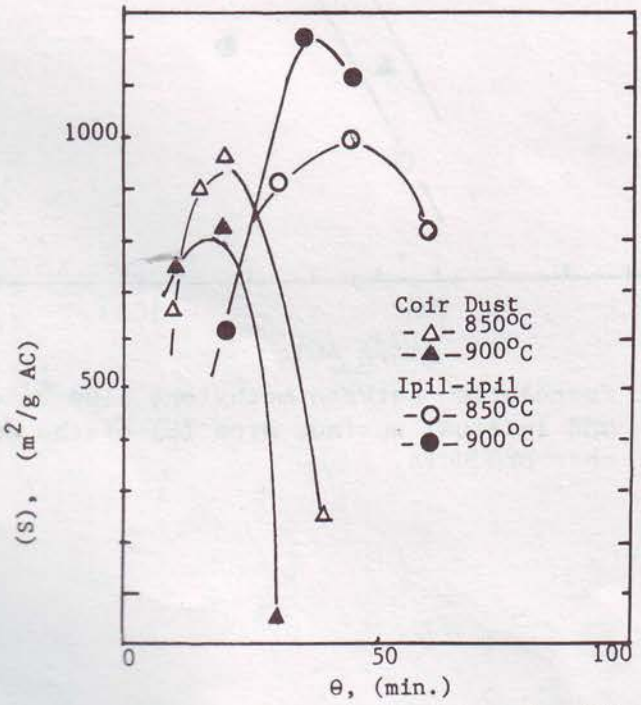


Fig. 5. Effect of reaction time (θ) on internal surface area (S) of the activated char products.

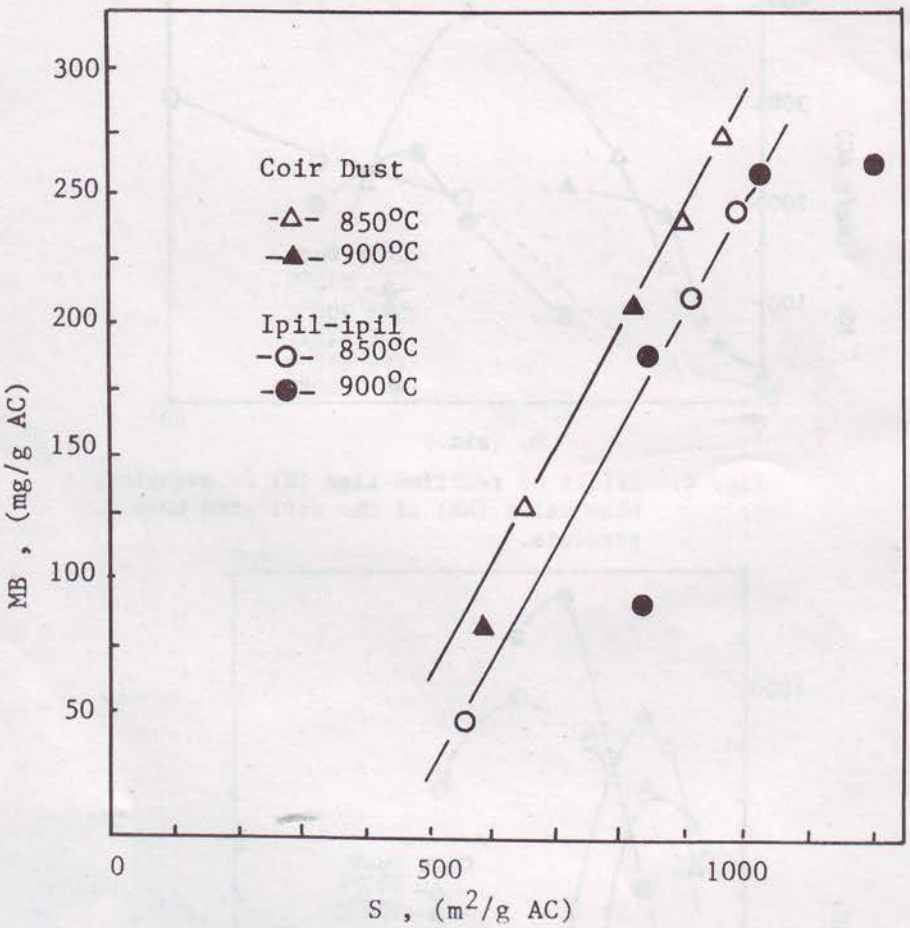


Fig. 6. Correlation between methylene blue value (MB) and internal surface area (S) of the activated char products.

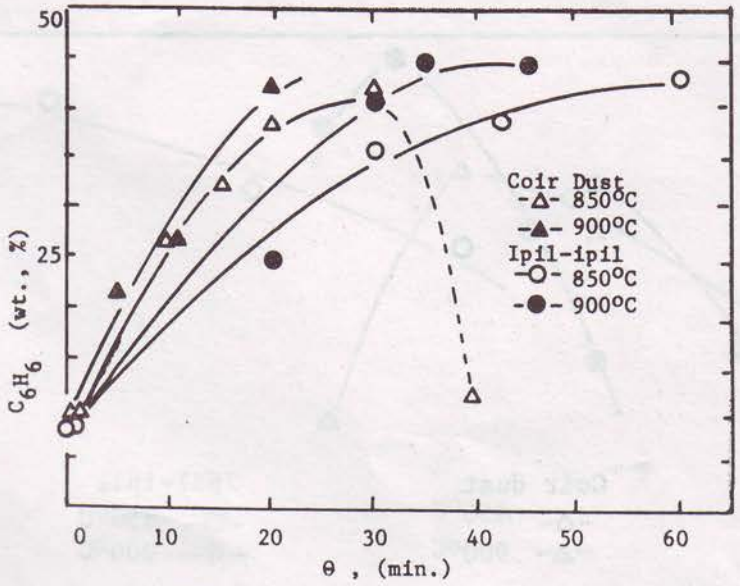


Fig. 7. Effect of reaction time (θ) on benzene adsorbability at 25°C.

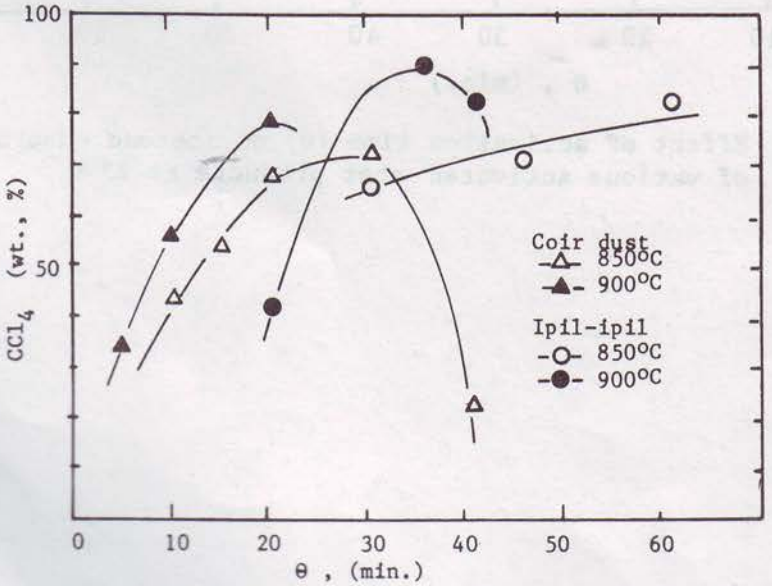


Fig. 8. Effect of reaction time (θ) on carbon tetrachloride adsorbability of various activated char at 25°C.

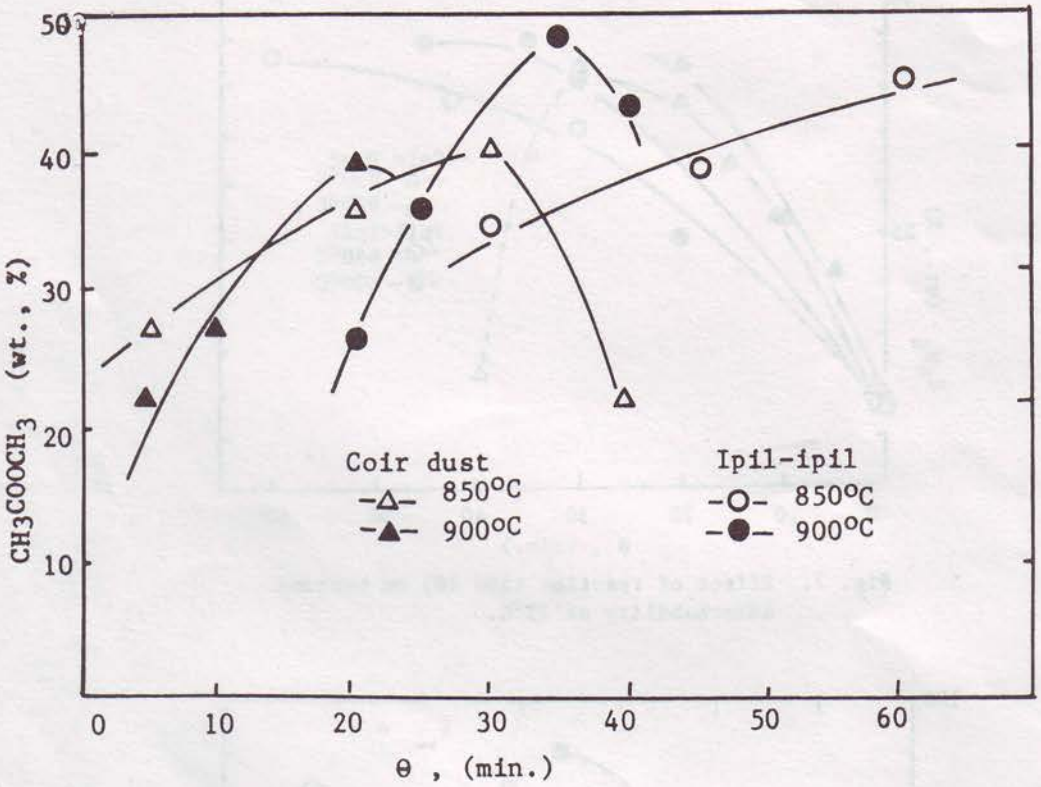


Fig. 9. Effect of activation time (θ) on acetone adsorbability of various activated char products at 25°C

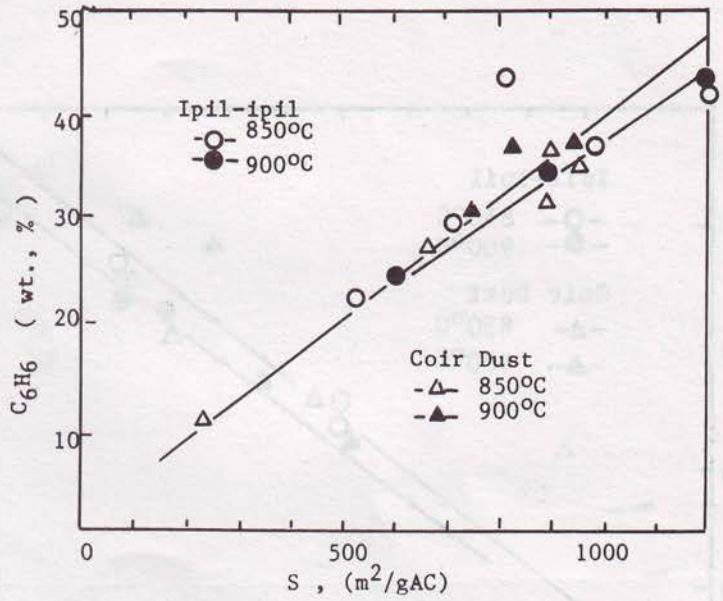


Fig. 10. Correlation between benzene adsorbability and internal surface area(S) of various activated char products.

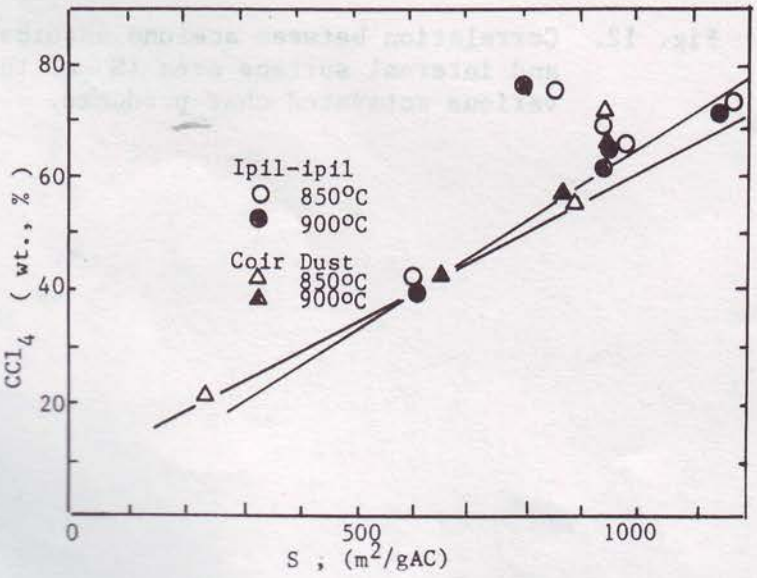


Fig. 11. Correlation between carbon tetrachloride adsorbability and internal surface area(S) of the various activated char products.

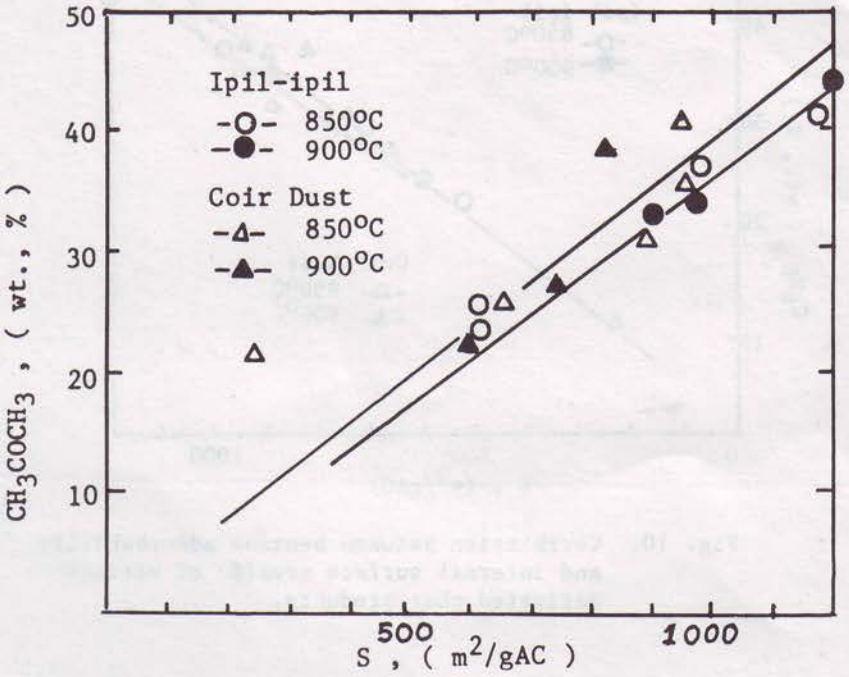


Fig. 12. Correlation between acetone adsorbability and internal surface area (S) of the various activated char products.

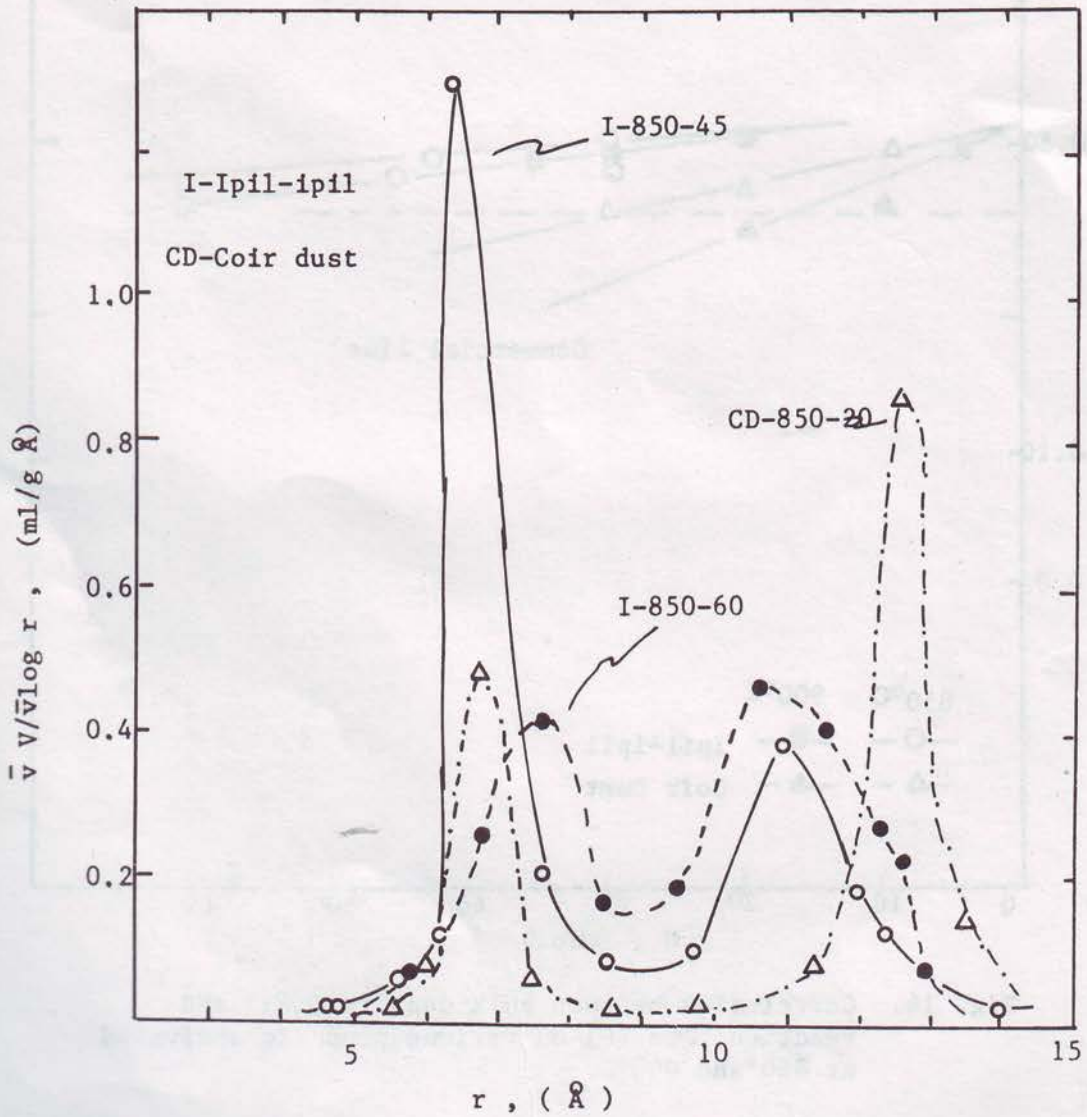


Fig. 13.. Pore size distribution curve of various activated carbon products.

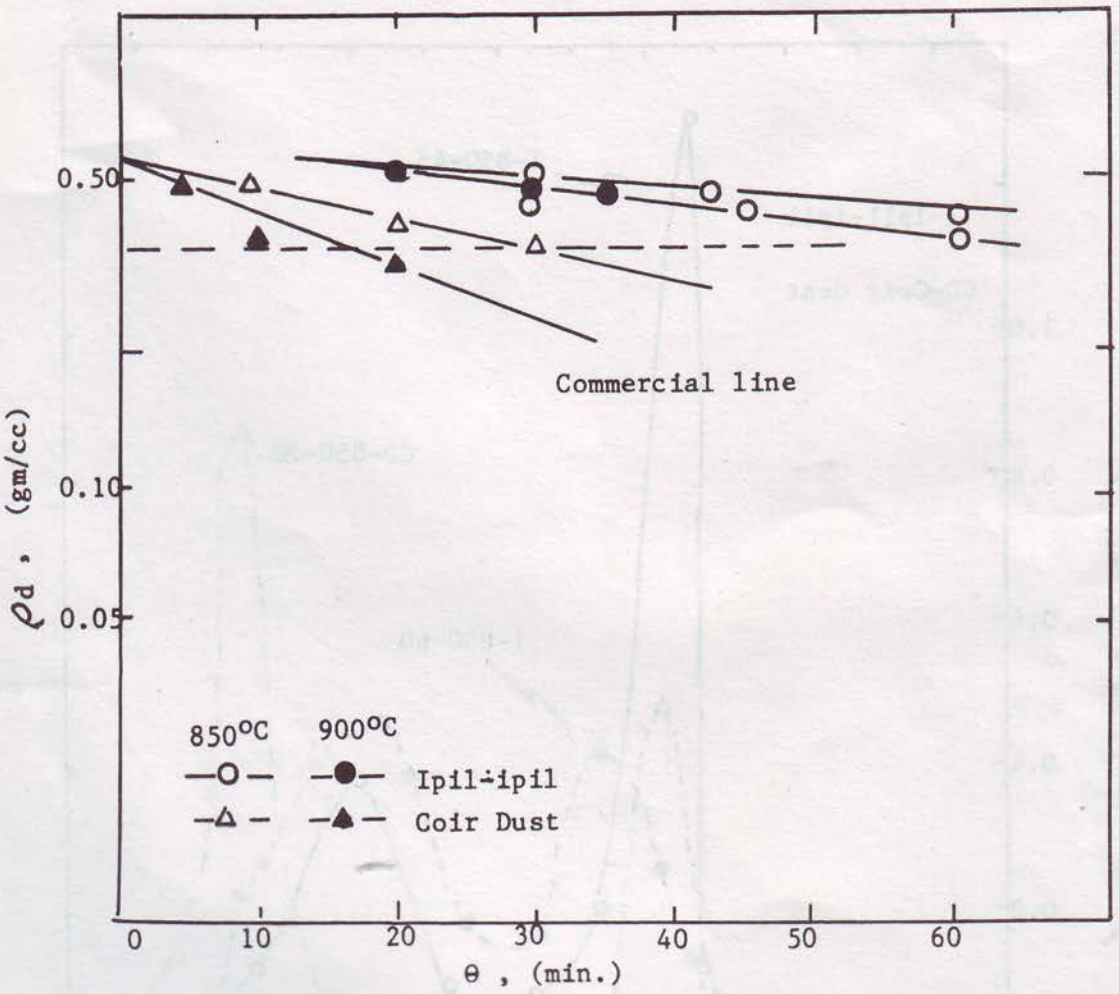


Fig. 14. Correlation between bulk density (ρ_d) and reaction time (θ) on various products activated at 850° and 900°C.